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THE MESOZOIC STRATIGRAPHY OF ALASKA

BY

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PREFACE

By Alfred H. Brooks

Before the middle of the nineteenth century Russian explorers found Mesozoic fossils on the Alaska Peninsula, and these were indeed the first features of geologic interest definitely recognized in the Territory. With the progress of areal geologic surveys during the last 25 years it has gradually come to be realized that the Mesozoic rocks, because of their widespread distribution and the great range in the periods of their deformation and intrusion, afford the most important clues to the geologic history of Alaska. The deciphering of the Mesozoic history is not only all-important to an understanding of the geology but it has a direct bearing on the mineral resources of the Territory. The intrusions of Jurassic and Cretaceous time were accompanied by the most intense metallization that has occurred in Alaska; the best known oil-bearing formation is of Mesozoic age; and valuable coal deposits occur in Mesozoic strata. Therefore, although this volume deals not at all with economic geology, the results here set forth have a very important bearing on that subject.

George C. Martin began his work on Alaska Mesozoic geology on his first trip to the Territory, in 1903, when his purpose was a preliminary study of the coal and petroleum resources of its Pacific seaboard. In the succeeding years he has done field work in Alaska during 17 seasons, most of it in Mesozoic areas, and has therefore acquired an intimate personal knowledge of the field occurrences of the rocks of this era. His field studies of the Mesozoic rocks have taken him through southeastern Alaska, the Chitina Valley of the Copper River Basin, Kenai and Alaska Peninsulas, the Iliamna Lake region, Matanuska Valley, Yukon Valley, and parts of the upper Kuskokwim River Basin. The wide distribution of the Mesozoic rocks of course makes it impossible for any one individual to study personally all the occurrences; moreover, Mr. Martin's field work on his chosen problem was much interrupted by incursions into other geologic fields, notably the subject of mineral fuels, and by important administrative duties. Therefore, in spite of the fact that he has established the present standard section of the Mesozoic forma-

tions in the regions which he has investigated, were he summarizing only his own observations this volume would be very incomplete. As is shown in the following pages, however, he has drawn very extensively on the work of others. Since Mr. Martin's work was started, more than 20 years ago, two score geologists have mapped and investigated areas of Mesozoic rocks in Alaska. Their results are summarized in this volume.

Necessarily, the results here set forth are in a large measure based on the work of paleontologists—largely on that of T. W. Stanton, who himself devoted a season to Alaska field work. Mesozoic fossil studies by F. H. Knowlton and J. B. Reeside, jr., are also cited.

This volume was first planned about 15 years ago, and Mr. Martin has given such time to its preparation as other important duties permitted. It is part of a large plan to prepare a summary volume on the geology of Alaska, the facts about which are now widely scattered through many publications. This summary will be more serviceable when the geologic map of Alaska, now in preparation, becomes available.

THE MESOZOIC STRATIGRAPHY OF ALASKA

By George C. Martin

SCOPE AND PURPOSE

One of the most valuable results of the investigations made by the Geological Survey in Alaska has been the discovery of thick sections of marine Mesozoic strata in many parts of the Territory. These strata are of extreme interest, not only because they occupy so large a part both of the area and of the stratigraphic section of Alaska that an intimate knowledge of them is essential for a full understanding of the local geologic features, but because they show significant relations with the known sections in other regions and because they will, when thoroughly studied, undoubtedly be found to constitute one of the most extensive and complete sections of much of the Mesozoic, especially of the Jurassic and Upper Triassic rocks, in North America, if not in the world. They will fill out the American stratigraphic column at points where it is very deficient in many other parts of the continent.

It has become evident that the rocks of Alaska offer very valuable contributions not only to mineral wealth but to pure science. In the acquisition of Alaska we received a European and Asiatic inheritance, both historically and geologically, for much of Alaska is essentially Russian in its geologic as well as in its human history. It is not a mere accident that the most elaborate publication on Alaskan fossils deals with faunas from the shores of both the Caspian Sea and the Alaska Peninsula. It is perhaps a fortunate circumstance that the best of the early collections of Alaskan Jurassic ammonites are in Europe, where they are accessible for comparison with the closely related European and Asiatic forms. The lately terminated Russian dominion on the eastern shore of the North Pacific followed most fittingly the often-repeated submergence of parts of both Alaska and Russia beneath a common sea in Permian, Triassic, Jurassic, and Cretaceous time.

Although no intensive stratigraphic and paleontologic studies of Alaskan Mesozoic rocks have yet been undertaken, except for Hollick's monograph of the Upper Cretaceous floras, for the description by J. P. Smith of some of the Upper Triassic fossils, and for

preliminary studies by W. R. Smith on some of the Upper Cretaceous invertebrates, nevertheless a large number of important stratigraphic data have already been accumulated. These data are partly unpublished and partly scattered through a large number of reports on regional and economic geology, where they are not so accessible as they should be, nor is their volume and significance fully appreciated.

There is need for a general preliminary discussion of these rocks in order to call attention to the available information and thus render it more accessible, and also, so far as possible, to coordinate the known facts, present some important conclusions, and set forth some of the problems which further studies of the Alaskan rocks may help to solve or for the solution of which additional facts from other regions are necessary. With this purpose the writer presented to the Geological Society of America in December, 1911, the outline[1] of a paper entitled "The Mesozoic stratigraphy of Alaska." The work begun at that time has developed into a rather extensive and elaborate treatise on the Mesozoic rocks of Alaska, which, although primarily a summary of existing knowledge, is to a large degree based on special field investigations the results of which have not hitherto been published except for general descriptions of the Triassic rocks[2] and for various conclusions cited in regional reports that have been written while these studies were under way. The Upper Cretaceous plant-bearing beds are described in a monograph that has not yet been sent to press.[3]

The general scheme of the work includes a division of the volume into three sections—on the Triassic, Jurassic, and Cretaceous. Each section includes general discussions of the areal occurrence, stratigraphic sequence, correlation, and geologic history and detailed descriptions of local sections by regions arranged approximately in geographic sequence, beginning with the region in which the rocks of the particular system are best developed or best known. In each detailed regional description there is a general discussion followed by an account of each formation. The description of each formation includes a historical review in which all previous descriptions are cited and briefly summarized; a stratigraphic description, which may include a summary or quotation of some previous description or a new description based on the writer's field observations; and a discussion of age and correlation, which includes lists of fossils, many of them not hitherto published, abstracts or quotations of published

[1] Geol. Soc. America Bull., vol. 23, pp. 724–725, 1912.

[2] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 685–718, 1916.

[3] Martin, G. C., The Upper Cretaceous plant-bearing beds of Alaska (in Hollick, Arthur, The Upper Cretaceous floras of Alaska): U. S. Geol. Survey Mon. — (in preparation).

or unpublished discussions by paleontologists, and the writer's own conclusions concerning the stratigraphic position and correlation of the formation. Some rocks of possible Mesozoic age which can not be referred definitely to the Triassic, Jurassic, or Cretaceous are described briefly in a final section.

Acknowledgments should be made to the many geologists, cited below, who made the field observations that are the basis of the descriptions here given, and also to the paleontologists whose determinations of the fossils are the substantial basis of the conclusions here presented. It should be remembered that these field observations have been gathered, for the most part, in the course of pioneer reconnaissance investigations and necessarily are scanty and generalized. It should be remembered also that the fossils have not yet been exhaustively studied. The determinations of genera and species can be accepted as definite, except where a doubt is expressed; but no attempt has yet been made to list all the species, many of which are undescribed, or to determine the precise relations of the faunas to those of other regions. The writer has based his interregional correlations of the Triassic rocks largely on the published results of Prof. J. P. Smith's elaborate studies and correlations of the Triassic rocks of California, Nevada, and Oregon. Professor Smith should not, however, be held responsible for the correlations of the Alaska and British Columbia rocks except where he is directly cited.

TRIASSIC SYSTEM

OCCURRENCE AND GENERAL CHARACTER

Triassic rocks are widely distributed in Alaska, being now known at many localities (see fig. 1) in nearly all parts of the three major mountain regions, though absolutely restricted to those regions. The most striking fact regarding the distribution of Triassic rocks in Alaska is this remarkable agreement between the areas of present Triassic outcrops and the areas of the major mountain regions. In this respect conditions in Alaska are in accord with those in many other parts of the world. The marine Triassic is, with good reason, called the alpine Trias, for in Alaska, as in the Alps, in the Himalayas, and in the western part of the United States and of Canada it is generally if not invariably restricted to mountain regions of the alpine (structural) type. The general world-wide geographic accordance of the present areas of marine Triassic rocks with mountains of alpine form, structure, and date has previously been recognized and has been stated by Frech[4] as follows:

[4] Frech, Fritz, Rückblick auf die Trias: Lethaea geognostica, Teil II, Band 1, Lief. 4, pp. 510, 518, 1908.

Scarcely in any period of the earth's history is the connection between the distribution of mountain zones and later sedimentation so clearly expressed as in the Trias.

1. The provinces of the late Paleozoic folding correspond to the continental development of the Trias.

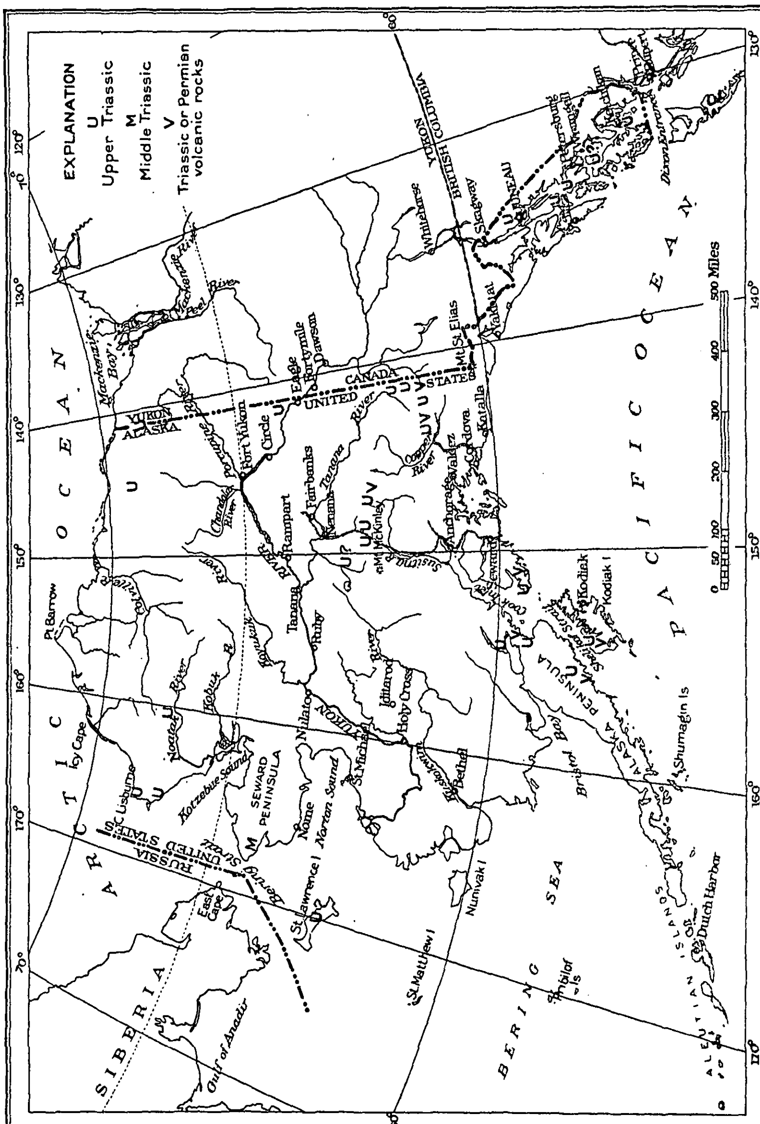

FIGURE 1.—Map of Alaska showing principal Triassic localities

2. The great Mediterranean Sea of Eurasia and the margin of the Pacific Trias-ocean coincide with the zones of the Tertiary high mountains. Only the eastern margin of the Cordilleras (that is, the Rocky Mountains of North America, in a strict sense) contain a continental development of the Trias.

3. The flat-lying Arctic Trias (Spitzbergen, North Siberia, Arctic (extra-Pacific) North America), where neither late Paleozoic nor Tertiary mountain

building is encountered, can not be regarded as an exception to the above rule but belongs, in a tectonic sense, to an indifferent province.

The dependence of the distribution of the oceanic Trias on the later Alpine—that is to say, Eurasian and circum-Pacific—folding has been repeatedly emphasized and means essentially that the accumulation of thick masses of sediments in the geosynclines determines the later folding. From northern Spain, the Balearics, Sicily, the Alps, and Dinarics to the Himalayas and Sumatra the same uniform law holds that also governs on the circumference of the Pacific Ocean. Here we see also from Alaska, Kamchatka, and Japan to New Caledonia, New Zealand, California, Mexico, Colombia, and Peru the oceanic Trias constantly appearing in the provinces of Tertiary mountain building, which, without exception, are coincident with a great thickness of sediments.

The Alaskan Triassic is noteworthy not only because it affords an additional example of the law stated by Frech but because the law holds there in such remarkable detail.

All the Triassic rocks of Alaska that are now known belong in the Upper Triassic, except for a single area of Middle Triassic rocks on Seward Peninsula. It is probable that the Lower Triassic and much of the Middle Triassic are not represented in the Alaska rocks, except possibly by terrestrial volcanic rocks or by some metamorphosed strata of very doubtful age.

CHARACTER OF THE PRE-TRIASSIC BASEMENT

Permian (?) strata.—The youngest rocks of known age that underlie the Triassic beds of Alaska are early Permian (?) limestones. These limestones carry a fauna closely related to that of the Artinskian of Russia, which is regarded by some as pre-Permian but which is more generally considered as the lowest division of the Permian. These limestones are very widely distributed in Alaska, occurring in nearly all the larger geographic regions, and show that toward the end of the Paleozoic era (at about the beginning of Permian time) limestone-forming seas extended over the larger part if not all of the area that is now Alaska. Marine Permian deposits younger than the Artinskian are not known and probably are not present in Alaska.

Pre-Triassic (?) slate of undetermined age.—Throughout most of the mountains on the Pacific coast of Alaska are large areas of slaty rocks of very uncertain age. The evidence on the age of these rocks is scanty and conflicting, and all that can be safely said concerning it is that they may be as old as early Paleozoic or as young as Upper Cretaceous. It is practically certain that these rocks are, at least in part, older than Upper Triassic, and the writer believes that they are, at least for the most part, Paleozoic. They clearly underlie the lavas that are beneath the Upper Triassic limestones and tuffs of the Kenai Peninsula. (See pp. 45, 481–487.)

Early Triassic (?) volcanic rocks.—The Upper Triassic sedimentary rocks described below are underlain in many places throughout the Pacific Mountain belt by volcanic rocks that include both lavas and tuffs and that have in some places been described as greenstones. These rocks include the Nikolai greenstone of the Chitina Valley, the basic lavas and tuffs of the upper Susitna Valley, the ellipsoidal lavas of Kenai Penensula and Kodiak Island, some of the greenstones of the Iliamna-Clark Lake district, and the ellipsoidal lavas of Hamilton Bay, in southeastern Alaska. In all these districts they clearly underlie the marine Upper Triassic strata without recognizable unconformity. It is only in the Chitina Valley that the basal contact of these rocks with underlying beds of known age has been observed. Here they rest on Carboniferous tuffs, cherts, and slates. In the Kenai Peninsula, on Kodiak Island, and probably on the west shore of Cook Inlet they overlie the slaty rocks of unknown age that are described above. On Hamilton Bay they are probably underlain by lower Permian (?) limestones. These volcanic rocks may include also the greenstone associated with the Orca group of Prince William Sound, as well as part of the greenstones of southeastern Alaska. They may possibly be correlated with the lavas and tuffs beneath the Permian (?) limestone of White River, but it is more probable that they are either Permian or early Triassic.

LOCAL SECTIONS

CHITINA VALLEY

GENERAL FEATURES

The most complete known section of Triassic rocks in Alaska is in the Chitina Valley, where there are several thousand feet of marine Upper Triassic strata, mostly shale and limestone, resting with apparent conformity on a thick series of lava beds (Nikolai greenstone) whose precise age has not been determined but which are probably either Triassic or late Paleozoic (Permian?). The Triassic strata are overlain unconformably by Jurassic and Cretaceous rocks, which are described farther on.

There are notable differences between the sections exposed in different parts of the Chitina Valley, as is shown by the two following sections, which are characteristic of the east and west ends:

General section of Triassic rocks in the Nizina Valley

	Feet
Upper Triassic:	
McCarthy formation: Black shale, with a few thin beds of limestone and with much thin-bedded black chert at the base. Contains *Pseudomonotis subcircularis*	1,500–2,500

	Feet
Upper Triassic—Continued.	
Conformity(?).	
Nizina limestone: Thin-bedded limestone, becoming shaly toward the top. No fossils yet found	1,000–1,200
Conformity.	
Chitistone limestone: Massive bluish-gray limestone, with *Halobia* cf. *H. superba*, *Terebratula*, *Spiriferina*, *Tropites*, *Juvavites* (?), *Arcestes*, and *Atractites*	1,800–2,000
Conformity(?).	
Triassic or Permian:	
Nikolai greenstone: Basaltic lava flows	4,000–5,000
Basal contact and underlying rocks not exposed.	

General section of Triassic rocks in the Kotsina and Kuskulana valleys

	Feet
Upper Triassic:	
Kuskulana formation: Black shales, with a few thin beds of limestone. Contains *Pseudomonotis subcircularis*	2,000 ?
Unconformity(?).	
Thin-bedded limestone, with some intercalated shale, including Nizina limestone. Contains *Orbiculoidea?*, *Halobia* cf. *H. superba*, *Myophoria?*, *Pecten*, *Tropites*, *Juvavites?*, *Ceratites?*, and *Arcestes?*	500–3,000 ?
Conformity(?).	
Chitistone limestone: Massive gray limestone, with *Terebratula*, *Spiriferina*, *Avicula*, *Halobia* cf. *H. superba*, *Gryphaea?*, *Myophoria*, *Pecten*, *Hinnites?*, *Pleuromya*, *Tropites?*, and *Arcestes*	75–700 +
Conformity(?).	
Triassic or Permian:	
Nikolai greenstone: Basaltic lava flows	6,500
Underlain conformably(?) by early Carboniferous beds.	

NIKOLAI GREENSTONE (PERMIAN OR TRIASSIC)

Historical review.—The Nikolai greenstone was named and first described by Oscar Rohn,[5] who made an exploratory journey through the Chitina Valley in 1899. Rohn recognized the fact that the Nikolai greenstone is older than the Chitistone limestone, which was then considered Devonian or Carboniferous, and consequently assigned it to the Silurian. The "bedded volcanics" at the head of Kotsina River, which Rohn described[6] as distinct from the Nikolai greenstone, were considered by some later writers part of it, but they

[5] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 425, 426, 431, 433, 1900.
[6] Idem, pp. 420–421.

have recently been separated as the Strelna formation, which is now known to be early Carboniferous.

The Nikolai greenstone was described in considerable detail by Schrader and Spencer,[7] who made a geologic reconnaissance of the Chitina Valley in 1900. They referred this formation to the Devonian and described it as including not only the original Nikolai greenstone of Rohn but also the underlying tuffaceous beds that were not included in the original description and that are now known to be Carboniferous. It was described by Mendenhall and Schrader[8] on the basis of a brief examination of the ore deposits of the Kotsina Valley by Mendenhall in 1902. They regarded it as of Carboniferous age and assigned to it the same limits as Schrader and Spencer. A later description, based on the same field work, was given by Mendenhall,[9] who discussed at length the problem of age, concluding that it is either Carboniferous or else "early Triassic or late Permian."

The account of the Nikolai greenstone by Moffit and Maddren[10] includes a general description, mostly quoted from Schrader and Spencer, and a large amount of local detail scattered through the "description of properties." The investigations upon which this account were based had as their primary object the study of the copper deposits, and no attempt was made to revise either the geologic map or the geologic descriptions of Schrader and Spencer, except as such work could be done incidentally to the examination of the ore deposits. The most important contribution by Moffit and Maddren to our knowledge of these rocks is their description[11] of the tuff, chert, and slate and their suggestion that these beds should be separated from the rest of the formation. This would be practically a return to Rohn's original usage. It should be noted that this suggestion has subsequently been carried out (see p. 9) and that these beds have been found to contain early Carboniferous (Mississippian) fossils.

The character of the Nikolai greenstone in the Nizina Valley has been described in detail by Moffit and Capps.[12] The area covered in their report includes the type locality of the formation, and in this area the tuffaceous beds that underlie the lavas of the original Nikolai greenstone are not exposed. Consequently the use of the for-

[7] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special pub.), pp. 33, 40–43, 1901.

[8] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, p. 14, 1903.

[9] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 26, 39, 50–51, 1905.

[10] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Kuskulana region, Alaska: U. S. Geol. Survey Bull. 374, pp. 21, 23–25, 54–92, 1909.

[11] Idem, p. 24.

[12] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 60–63, 1911.

mation name by Moffit and Capps is identical with the original usage by Rohn.

The Nikolai greenstone and the underlying tuffaceous rocks of the upper Chitina Valley have been described briefly by Moffit[13] as "Triassic (?) and Carboniferous greenstones" and in greater detail by Overbeck[14] as "tuffs and flows of Carboniferous and Triassic (?) age." The lavas that were correlated with the typical Nikolai greenstone were not mapped separately from the underlying and presumably early Carboniferous tuffs, but the distinction was recognized in the description.

A detailed account of the character and occurrence of the Nikolai greenstone in the Kotsina and Kuskulana Valleys has been given by Moffit and Mertie,[15] who have restricted the term Nikolai greenstone to the lavas that overlie the early Carboniferous tuff, lava, chert, limestone, and shale described as the Strelna formation. This is practically a return to the original usage of Rohn and also of Moffit and Capps. A detailed description of the petrographic character and a discussion of the age of the Nikolai greenstone were given by Mertie.[16]

Character.—The Nikolai greenstone is made up of a succession of well-bedded lava flows aggregating at least 4,000 feet, and possibly 5,000 feet, in thickness in the Nizina Valley and about 6,500 feet in the Kotsina and Kuskulana Valleys. The rock is a typical diabase, in a well-advanced and general degree of alteration. Interbedded tuffaceous or sedimentary strata have not been observed in the Nikolai greenstone proper, although they occur in the underlying beds that some authors have included in it.

In the Chitina Valley it occurs on the southern slope of the Wrangell Mountains, or in that part of the valley lying north of the river. It is believed to be generally present throughout this area, although buried by younger rocks over considerable tracts. Its areal distribution at the surface is indicated on several published maps accompanying the reports cited above.

Age.—The basal contact of the Nikolai greenstone is not known, and there is consequently no evidence of its relations to any Paleozoic rocks, except in the Kotsina and Kuskulana Valleys, where it rests upon early Carboniferous tuff, chert, and slate. It is overlain by the Chitistone limestone, described below, without evidence of unconformity. It has hitherto been correlated with lava and tuff beds

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[13] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey, Bull. 675, pp. 17, 18, 68–69, pl. 3, 1918.

[14] Overbeck, R. M., Igneous rocks [of the upper Chitina Valley]: U. S. Geol. Survey Bull. 675, pp. 62–64 1918.

[15] Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 18, 19, pl. 3, 1923.

[16] Mertie, J. B., jr., Igneous rocks [of the Kotsina-Kuskulana district]: U. S. Geol. Survey Bull. 745, pp. 58–67, 1923.

which are exposed in the valley of Skolai Creek and at the head of White River and which appear to rest conformably upon an upper Carboniferous limestone, but as shown on page 35 this correlation must be rejected. It is possible, however, that the Nikolai greenstone represents the lava and tuff below the upper Carboniferous limestone of White River. The most definite conclusion that can be made at present is that the Nikolai greenstone is probably either Permian or early Triassic.

CHITISTONE LIMESTONE

Historical review.—The Chitistone limestone was named by Rohn,[17] who sometimes called it the "Nizina limestone," but the use of the latter name was evidently unintentional. The original description is very general, the formation being defined as "a massive bed of limestone 500 or more feet thick." No section or stratigraphic details were given, and the limits of the formation were not defined, except by the statements that it overlies the Nikolai greenstone and is overlain by "a series of soft black, highly fissile shales and slates." Rohn referred the limestone tentatively to the Carboniferous or Devonian.

The Chitistone limestone was mapped and described in greater detail by Schrader and Spencer,[18] who assigned it to the Carboniferous on the basis of a correlation with the Carboniferous limestone of Skolai Pass and White River. They described it as "composed of very massive limestones without any important intercalations of shale" and as having a thickness, in the type area, of about 2,000 feet. It is shown below (p. 13) that this estimate of the thickness is approximately correct. The position of the boundary between the Chitistone limestone and the overlying formation was discussed as follows:

> Studies * * * have not been sufficiently detailed to afford evidence as to where the line between these two formations should be drawn. Above the massive basal series of limestones there is a series of thin-bedded limestones with shaly partings, which is apparently in perfect conformity with the underlying beds and which passes by gradation into the black shales above. These black shales contain the fossils by means of which the Triassic age of the formation has been determined. The provisional and arbitrary line between the two formations has been placed at the top of the massive limestone series.

Schrader and Spencer were consistent in their attitude on this point and defined the overlying formation as including a basal member, 1,000 feet thick, which rests conformably upon the Chitistone lime-

[17] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 425, 426, 427, 431, 433, 434–435, 1900.

[18] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), pp. 32, 33, 44–46, 1901.

stone and which consists of "a series of thin-bedded limestones, in strata from a few inches to a foot or more in thickness, separated by thin partings of black shale." These beds were included by Moffit and Capps in the Chitistone limestone. (See p. 12.)

The description of the Chitistone limestone by Mendenhall and Schrader [19] is very brief and contains no new data, except in the descriptions of the mineral deposits, with which their report is chiefly concerned.

The account by Mendenhall,[20] who correlated the Chitistone limestone provisionally with the upper Carboniferous (Pennsylvanian and Permian) Mankomen limestone of the Alaska Range and described and mapped it under the name Mankomen, contains very little new descriptive matter relative to the Chitistone limestone. Mendenhall discussed the age and correlation of this formation in great detail, pointing out that there were strong reasons in favor of its assignment to the Triassic.

The Chitistone limestone was first referred definitely to its proper position in the Triassic by Moffit and Maddren.[21] Their general description of the formation is quoted from the account by Schrader and Spencer, but the discussion of its age, with the accompanying lists of fossils, is new, as is also considerable information given under the "description of properties."

The Chitistone limestone of the Nizina Valley has been mapped and described in detail by Moffit and Capps,[22] who extended its upper limit to include the thin-bedded limestone which Schrader and Spencer regarded as the lower member of the overlying formation.

A general account of the Chitistone limestone, based chiefly on the descriptions by previous observers, but presenting some new information, including lists of fossils, has been given by Martin,[23] who restricted the formation to the massive limestone.

The Chitistone limestone of the upper Chitina Valley was described briefly by Moffit.[24]

A detailed account of the occurrence of the Chitistone limestone in the Kuskulana and Kotsina Valleys has been given by Moffit

[19] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, pp. 14–15, 18–23, 1903.

[20] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 26, 47, 48–51, 1905.

[21] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 25–28, 54–92, 1909.

[22] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 21–28, 1911.

[23] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 690–693, 1916.

[24] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 25–26, pl. 3, 1918.

and Mertie,[25] who restricted the formation to the massive limestone, which is 75 to 700 feet thick in that district. They thus brought the limits of the formation back to approximately the position assigned by Schrader and Spencer and the other early observers. The description by Moffit and Mertie includes detailed information concerning the distribution, character, thickness, structure, age, and correlation, with a table showing the occurrence of fossils.

Stratigraphic description.—The Chitistone limestone crops out in many discontinous areas throughout the south front of the Wrangell Mountains from Chitistone River to Cheshnina River or throughout the part of the Chitina Valley that lies north of Chitina River. It has not been recognized south of the river.

The stratigraphic position of this limestone relative to the other formations of this district is clearly defined, for it rests everywhere with apparent conformity upon the Nikolai greenstone and is overlain at most places by the Nizina limestone and the supposedly equivalent thin-bedded limestones in the lower part of the Kuskulana formation. The contact of the Chitistone limestone with the Nizina limestone and its supposed equivalents is everywhere apparently conformable. In many places the rocks overlying the Chitistone limestone are Jurassic or Cretaceous and rest with a very pronounced unconformity upon not only the Chitistone limestone but also upon the other Triassic formations.

The Chitistone limestone of the type area was described by Moffit and Capps[26] as being about 3,000 feet thick, but this thickness and their description quoted below include the thin-bedded Nizina limestone.

In the Nizina district the lower part of the Chitistone formation is made up of thick, massive beds of a dark-gray or bluish-gray color, but weathering to a lighter gray on the surface. The upper part, on the other hand, is made up of thinner beds, and this thinness increases toward the top. A slight difference in chemical composition between the upper and the lower parts of the Chitistone limestone is indicated by the brownish-yellow weathering of the upper part. Changing conditions of sedimentation are indicated, too, in a more noticeable way by the appearance of thin shale beds at the top of the formation. This limestone is the oldest of the sedimentary formations exposed within the mapped area and lies on the Nikolai greenstone conformably, exactly as if both were sedimentary formations deposited in the same sea and the limestone had been laid down on the greenstone before any movement or disturbance had taken place in the greenstone. This conformable relation holds true wherever the contact has been examined, although in many places it is found that there has been movement of the two formations along this contact surface. In several places a bed of red and green shale with a maximum thickness of about 5 feet was found to intervene between the limestone and the

[25] Moffit, F. H., and Mertie, J. B. jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 29–34, 1923.

[26] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 21–23, 1911.

greenstone, but it is not known whether the shale is widely distributed or not, since the limestone-greenstone contact is nearly everywhere covered with talus. The shale is present in the vicinity of Bonanza mine and on Kennicott Glacier.

Excellent sections of the Chitistone limestone are seen on the west side of Nizina River, opposite the mouth of Chitistone River, and on McCarthy Creek. On McCarthy Creek the lower part of the formation, which dips about 30° NE., consists of massive beds of bluish-gray limestone, making up approximately three-fifths of the total thickness. Above this lower massive portion is a succession of more thinly bedded limestone strata weathering a rusty-yellow color and making up the remaining two-fifths of the formation. The thickness of individual beds decreases from the base toward the top, as has been stated, and near the top thin beds of black shale make their appearance. Then comes an indefinite thickness, approximately 300 feet, of thin-bedded limestone and shale,[27] overlain in turn by a great thickness of black shale, which Rohn called the McCarthy Creek shale. It is thus seen that there is a transition from the bedded limestones below through interbedded thin limestones and shales to shale above, and it is readily understood that difficulty arises in choosing a definite dividing plane between these two formations.

The thickness of the Chitistone limestone as restricted above is approximately 2,000 feet on Nikolai Creek. The thickness on McCarthy Creek was estimated by Moffit and Capps at about 1,800 feet. In the hills between Kennicott Glacier and Fohlin Creek the thickness is at least 1,500 feet and may be 2,000 feet or more. On the tributaries of Kuskulana and Kotsina Rivers, in the western part of the Chitina Valley, the Chitistone limestone seems to be reduced to a single massive plate which is, in general, not more than 75 to 700 feet thick. The Chitistone limestone thus apparently thins toward the west, whereas the overlying Nizina limestone grows thicker. The exposures in the intervening district have not been studied in detail, so it is unfortunately not known whether there is a gradual change from the one section to the other. It is possible that the apparent westward thinning of the Chitistone limestone may be due to the cutting out of parts of the formation, in some places by faults and in other places by unconformity, and the apparent westward thickening of the overlying Nizina limestone may be caused by structural repetition of the beds. If the apparent westward thinning of the Chitistone limestone exists as a purely stratigraphic feature, it may be due to the variation in the volume of the original sediments, the limestone having been deposited in the form of a wedge-shaped plate thinning westward; or it may be due to variation in the character of the original sediments, the massive limestone beds of the eastern area grading westward into thin-bedded limestone and shale; or may be due to subsequent erosion.

Age and correlation.—The fauna of the Chitistone limestone, as shown in the following table, consists wholly of marine invertebrates.

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[27] Moffit and Capps did not intend to include these beds in the Chitistone limestone and mapped them as part of the overlying McCarthy shale.—G. C. M.

Fossils from the Chitistone limestone [a]

	6319	6320	6333	4810	6321	8885	8884	8882	8883	6306	6312	8886	8887	6303	6330	11384	11385	11386	6300	4808	4809	2209	11366	9960	10251	10252	10253	10254	9946	9948	9919	9927	9929	8925	8148	8946	2194	8938	4805 (3-6)	4805 (2, 23)	8152	8164	8159	8931	8923	8932	8165	8167	8166	4806
Thecosmilia?																	b																																	
Thamnastraea																																																		
Thamnastraea?																b	b																																	
Spongiomorpha?																	b																																	
Undetermined corals																				a																														
Corals?																			a																															
Corals? (large radiating masses, inorganic?)								a																												a														
Pentacrinus																						a																												
Isocrinus cupreus Bather																					c																													
Isocrinus?																b																																		
Terebratula															a		b			a	a															a			a											
Spiriferina																	b			a																			a											
Spiriferina?				a																																														
Avicula																						a														a														
Avicula?																					a																													
?Pseudomonotis subcircularis (Gabb) [b]											a																																							
Pseudomonotis?																				a																														
Halobia cf. H. superba Mojsisovics		a	a		a	a	a					a		a									b			a	a	a	b		b	b	b													a				
Halobia cf. H. austriaca Mojsisovics																		b																																
Halobia (nearly smooth species)																															b																			
Halobia (with broad ribs)																												a					b																	
Halobia (small with fine ribs)																														b																				
Halobia				a									a			b																																		
Halobia? (as in 8923)																																						a						a	a	a				
Halobia?																																				a					a	a	a				a		a	
Gryphaea																						a																												
Gryphaea?																																				a							a		a			a		
Myophoria																b	b																			a														
Myophoria?									a																													a												
Pecten																																													a					
Pecten? (large coarse-ribbed species)																																												a						
Hinnites?																				a																			a											
Hinnites? cf. Halobia occidentalis Whiteaves																																					a			a										
Pleuromya																																				a														
Pleuromya?																																							a											
Undetermined pelecypods												a		a																																				a
Pleurotomaria (Sisenna)																	b																																	
Turbo																	b																																	
Turbo?												a																								a														
Pseudomelania?																																				a														
Natica?																	b																											a						a
Fusus-like gastropod																	b																																	

Undetermined gastropods																b																						a			a									
Orthoceras cf. O. shastense Hyatt and Smith																b																																		
Orthoceras											a																																							
Tropites (more compressed than T. subbullatus Hauer)																b																																		
Tropites	a																																																	
Tropites?				a																															a															
Discotropites aff. D. sandlingensis Hauer																b																																		
Juvavites? (2 species)											a																																							
Juvavites?										a											a																													
Trachyceras (Protrachyceras)																								b																										
Trachyceras?																b																																		
Arcestes		a	a	a						a	a					b	b								a																a									
Arcestes?						a	a					a	a				b				a													a																
Undetermined ammonite												a																			b									a					a					
Atractites												a	a																																					

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside, jr.; c, identified by F. A. Bather.
[b] This species was probably obtained in float material derived from the overlying beds.

6319. South side of Chitistone River, east side of lowest large tributary, about 4 miles above Nizina River. Near base of Chitistone limestone. F. H. Moffit, 1909.

6320. South side of Chitistone River, west side of lowest large tributary, about 4 miles above Nizina River. Near base of Chitistone limestone. F. H. Moffit, 1909.

6333. South side of Chitistone River, at Potter's mine, about 4½ miles above Nizina River. Near base of Chitistone limestone. S. R. Capps, 1909.

4810. South side of Chitistone River. Talus slide near Houghton-Alaska Co.'s prospect. F. H. Moffit, 1907.

6321. Mountain north of Texas Creek, Copper Creek valley. Probably well up in the formation. F. H. Moffit, 1909.

8885. Valley of Nikolai Creek, about a quarter of a mile east of Nikolai mine. About 500 feet above base of Chitistone limestone. G. C. Martin, 1914.

8884. Valley of Nikolai Creek, about 0.3 mile N. 70° E. of Nikolai mine. About 800 feet above base of Chitistone limestone. G. C. Martin, 1914.

8882. Valley of Nikolai Creek, about two-thirds mile east of Nikolai mine. About 1,000 feet above base of Chitistone limestone. G. C. Martin, 1914.

8883. Valley of Nikolai Creek, about two-thirds mile east of Nikolai mine, 200 or 300 yards northwest of 8882. From about 1,200 feet above base of Chitistone limestone. G. C. Martin, 1914.

6306. Valley of Nikolai Creek, about two-thirds mile northeast of Nikolai mine. About 2,000 feet above base of Chitistone limestone. F. H. Moffit, 1909.

6312. Valley of Nikolai Creek, northeast of Nikolai mine. F. H. Moffit, 1909. This lot was apparently obtained either from approximately the same locality as 6306 or from a locality about a quarter of a mile north of it. The writer believes that the material in this lot is probably mixed, the cephalopods coming from the Chitistone limestone at or near locality 6306 and the *Pseudomonotis* coming from the McCarthy shale at a locality about a quarter of a mile farther north.

8886. Valley of Nikolai Creek, small gulch 0.56 mile N. 50° E. from Nikolai mine. Boulder probably near the horizon of lot 6306. G. C. Martin, 1914.

8887. Valley of Nikolai Creek, about 0.6 mile N. 48° E. from Nikolai mine. Boulder probably from about the same horizon as 6306. G. C. Martin, 1914.

6303. Nikolai Creek. Boulder in bed of creek. F. H. Moffit, 1909.

6330. McCarthy Creek. Said to be 10 feet above base of Chitistone limestone. Given to F. H. Moffit, 1909.

11384(23). Upper part of Chitistone limestone on ridge between McCarthy Creek and East Fork. Elevation 5,000 feet. F. H. Moffit, 1922.

11385(24). Ridge between McCarthy Creek and East Fork. Elevation 5,100 feet. F. H. Moffit, 1922.

11386(24a). Same locality as 11385, in float that could not have traveled more than 50 feet. F. H. Moffit, 1922.

6300. Jumbo Creek, on spur 0.4 mile southwest of Bonanza Peak. Base of Chitistone limestone. F. H. Moffit, 1909.

4808. Near the Bonanza mine and Bonanza Creek. Talus material probably from the lower 1,000 or 1,500 feet of the Chitistone limestone. F. H. Moffit, 1907.

4809. Jumbo Creek near the Bonanza mine. Talus material, probably from lower 1,000 or 1,500 feet of the Chitistone limestone. F. H. Moffit, 1907.

2209. East side of Lakina Glacier. Limestone mapped as Chitistone. A. C. Spencer, 1900.

11366 (3). Top of ridge between west headwater branch of Gilahena River and west fork of Lakina River. F. H. Moffit, 1922.

9960 (F 42). Chokosna River. Chitistone limestone bluff, three-quarters of a mile southeast by east from mouth of creek flowing from Kuskulana Pass. Massive limestone. F. H. Moffit, 1916.

10251–10254. Berg Creek. F. H. Moffit, 1919.

9946 (F 28). Gulch tributary to Dry Creek from east at elevation 3,400 feet. Chitistone limestone in gulch at elevation about 3,700 feet. F. H. Moffit, 1916.

9948 (F 30). Locality 33. North fork of creek between Squaw and Clear Creeks; elevation, 2,900 feet. Float near base of cliffs of massive limestone. F. H. Moffit, 1916.

9919 (F 1). At bench mark 3664, on north fork of Strelna Creek. Thin, vertical limestone beds, in places shaly, 150 feet north of base of Chitistone limestone. F. H. Moffit, 1916.

9927 (F 9). East branch of east fork of Strelna Creek, 300 feet north of F 8, 100 feet higher on hill. Black thin-bedded limestone. F. H. Moffit, 1916.

9929 (F 11). North branch of east fork of Strelna Creek, 1,300 feet east-northeast of locality 10 (on north branch of east fork of Strelna Creek, at elevation of 4,250 feet, about 4,700 feet southwest of bench mark 6270). F. H. Moffit, 1916.

8925. 8,200 feet S. 67° W. from forks of east fork of Strelna Creek; elevation, 4,500 feet. F. H. Moffit, 1914.

8148. North fork of Strelna Creek on east side of first large creek near its mouth. Upper part of Chitistone limestone (?). F. H. Moffit, 1912.

8946. South fork of Rock Creek, on trail leading to west fork of Strelna Creek; elevation, 4,800 feet. Probably thin plate of Chitistone limestone. G. C. Martin, 1914.

2194. Near pass between head of Pass Creek and Rock Creek. Talus just under reef of heavy-bedded limestone. F. C. Schrader, 1900.

8938. About 11,800 feet S. 80½° E. from Alice Peak; elevation, 4,800 feet. F. H. Moffit, 1914.

4805 (3–6). Talus from lower 200 feet of Chitistone limestone on Copper Creek. Moffit and Maddren, 1907.

4805 (2, 23). Hoodoo or Mullen claim on Copper Creek. About 200 feet above base of Chitistone limestone. Moffit and Maddren, 1907.

8152. Clear Creek. Blue limestone above roadhouse. Theodore Chapin, 1912.

8164. Clear Creek. Theodore Chapin, 1912.

8159. Clear Creek. Talus slope below the Chitistone and the overlying thin-bedded limestone. Theodore Chapin, 1912.

8931. About 6,600 feet N. 44° E. of Dixie Pass; elevation, 5,500 feet. F. H. Moffit, 1914.

8923. West side of Lime Creek valley; elevation, 4,900 feet. Moffit and Mertie, 1914.

8932. About 5,850 feet N. 31° W. from Ammann's cabin on Kluvesna River. F. H. Moffit, 1914.

8165. Nugget Creek near forks. Fault block of Chitistone limestone. Theodore Chapin, 1912.

8167. Divide between Nugget and Roaring creeks. Theodore Chapin, 1912.

8166. Divide between Nugget and Roaring creeks. Theodore Chapin, 1912.

4806. Crawford's Skyscraper claim on Roaring Creek. Lower 100 feet of Chitistone limestone. Moffit and Maddren, 1907.

The table represents provisional identifications of 50 small collections from as many localities, distributed through practically the entire thickness of the formation. This list does not adequately

represent the complete fauna, for the collecting has been very far from exhaustive, and no attempt has been made to enumerate all the species, many of which are probably undescribed.

The list is sufficient to show the general aspect of the fauna, that it is certainly Upper Triassic, and that it probably belongs in the middle or Karnic stage of the Upper Triassic, being the equivalent of at least part of the Hosselkus limestone of California. Although most of the identified genera of brachiopods and pelecypods have a long range, yet both the character of many of the individual forms and the general aspect of the assemblage are unmistakably Triassic. The ammonites are all highly characteristic Upper Triassic genera and point strongly toward a horizon in the Karnic, as does also the pelecypod identified as *Halobia* cf. *H. superba* Mojsisovics, which is identical with the Californian species known by that name and is very closely related to *Halobia superba* of Europe, even though it may not be the same species. The Chitistone fauna belongs to the Mediterranean type of Triassic faunas and is indicative of warm-water conditions.

NIZINA LIMESTONE

Historical review.—The Nizina limestone comprises the rocks that were described by Schrader and Spencer[28] as the lower unnamed member of the "Triassic series" or "Triassic shales and limestones." Schrader and Spencer clearly recognized the fact that the rocks which they grouped as "Triassic shales and limestones" do not form a lithologic unit when they said[29] that "the Triassic series has not been called by the name proposed by Rohn, because it seems so complex that it will be eventually divided into several formations." They also indicated the proper basis for the main subdivision in the following statement:[30]

> In the lower part, and resting conformably upon the "Carboniferous" [Chitistone] limestone, is a series of thin-bedded limestones, in strata from a few inches to a foot or more in thickness, separated by thin partings of black shale. The thickness of this member is approximately 1,000 feet, and the limestone, so far as observed, did not contain fossil remains.

The Nizina limestone is part of the "Triassic shales and limestones" described by Mendenhall and Schrader.[31] Their account is very brief and general, the Nizina limestone being covered by the

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[28] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), pp. 32, 33, 46–47, 1901.

[29] Idem, p. 32.

[30] Idem, p. 46.

[31] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, p. 15, 1903.

statement that "the thin limestone beds are abundant near the base of the section, but toward the top they die out."

These beds were also included under the general designation "Triassic shales and limestones" by Mendenhall,[32] who gave a very brief description in which he indicated a twofold division of the rocks identical with that suggested by Schrader and Spencer.

A description of these rocks is also to be found under the heading "Triassic limestones and shales" in the account of the mineral resources of the Chitina Valley by Moffit and Maddren.[33] This account was quoted in full from the description by Schrader and Spencer, the reexamination of the ore deposits by Moffit and Maddren not having included a detailed examination of this formation, in which no prospects had been discovered.

The Nizina limestone, as the term is here used, includes part of the rocks described as the Chitistone limestone by Moffit and Capps.[34] It has already been shown on pages 11–12 that Moffit and Capps in describing the rocks of the Nizina district extended the Chitistone limestone to include thin-bedded limestone that was regarded by Schrader and Spencer as the lower member of the overlying formation. These beds were described by Moffit and Capps as follows:

> The upper part [of the Chitistone limestone], on the other hand, is made up of thinner beds, and this thinness increases toward the top. A slight difference in chemical composition between the upper and the lower parts of the Chitistone limestone is indicated by the brownish-yellow weathering of the upper part. Changing conditions of sedimentation are indicated, too, in a more noticeable way by the appearance of thin shale beds at the top of the formation. * * *
>
> Above this lower massive portion [of the Chitistone limestone] is a succession of more thinly bedded limestone strata weathering a rusty-yellow color and making up the remaining two-fifths of the formation. The thickness of individual beds decreases from the base toward the top, as has been stated, and near the top thin beds of black shale make their appearance. Then comes an indefinite thickness, approximately 300 feet, of thin-bedded limestone and shale,[35] overlain in turn by a great thickness of black shale, which Rohn called the McCarthy Creek shale. It is thus seen that there is a transition from the bedded limestones below through interbedded thin limestones and shales to shale above, and it is readily understood that difficulty arises in choosing a definite dividing plane between these two formations.

The Nizina limestone was first described under that name by Martin,[36] who included in it the rocks described by Schrader and

[32] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 26, 52, 1905.

[33] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 28–29, 1909.

[34] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 21–27, 1911.

[35] It was the intention of the authors to refer these beds to the overlying formation.—G. C. M.

[36] Martin, G. C., The Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 37, pp. 690, 693–694, 1926.

Spencer as the unnamed lower member of the "Triassic series" or "Triassic shales and limestones," and the rocks were described by Moffit and Capps as the upper part of the Chitistone limestone. The name Nizina limestone had previously been used a few times in Rohn's account of the geology of the Chitina Valley, being applied to the same beds that Rohn formally described as the Chitistone limestone. This previous use of Nizina limestone, however, appears only incidentally in the descriptions of other formations and of the structure and obviously was unintentional. The writer's account of the Nizina limestone includes a brief definition and description of the formation based chiefly on the work of earlier observers.

The description of the Chitistone limestone of the upper Chitina Valley by Moffit[37] contains a brief discussion of the Nizina limestone, which was included in the rocks represented as the Chitistone limestone on the map.

The western extension of the Nizina limestone in the Kotsina and Kuskulana Valleys is presumably represented by part of the rocks mapped by Rohn[38] as the Kuskulana shales and also part of the rocks represented on the same map as "unclassified sediments." Most of the rocks included under Rohn's description[39] of the Kuskulana shales carry the fauna of the McCarthy shale (see pp. 26, 29) and belong above the Nizina limestone.

The equivalent of the Nizina limestone in the Kotsina and Kuskulana Valleys is also believed to be represented in the rocks that Moffit and Mertie[40] described as the Kuskulana formation. The Kuskulana formation probably contains the lateral equivalent not only of the Nizina limestone but of part or all of the overlying McCarthy shale and possibly of some of the underlying Chitistone limestone. The description of the Kuskulana formation contains detailed accounts of the distribution, character, thickness, structure, age, and correlation of the rocks, with tables showing the occurrence of fossils. The relation of the Nizina limestone to the Kuskulana formation is discussed.

Stratigraphic description.—The Nizina limestone consists of a succession of thin-bedded limestones with a minor amount of interstratified shale. Massive limestone beds occur rarely throughout the formation, and a few thick beds of shale may be seen. There is a more or less gradual progressive change in the character of the formation from the base toward the top, the number and thickness of

[37] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 25–26, pl. 3, 1918.

[38] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pl. 52, 1900.

[39] Idem, pp. 423, 424, 425, 431–432, 433.

[40] Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745 pp. 18, 19–20, 35–44, pl. 3, 1923.

the limestone beds decreasing upward. The lower part of the formation consists at many places of practically all limestone, broken only by very thin shaly partings. The greater part of the formation consists of a fairly regular alternation of limestone and shale beds in about the proportion of 5 or 10 parts of limestone to 1 of shale; the limestone beds are from 4 to 18 inches thick and the shale beds from 1 to 3 inches thick. Toward the top of the formation the proportion of shale increases still more, there being a more or less gradual transition into the shales and thin limestones of the overlying McCarthy formation. The thickness of the beds here described as the Nizina limestone was estimated by Schrader and Spencer as approximately 1,000 feet, and by Moffit and Capps as about 1,200 feet. The latter estimate is approximately correct. The type section is in the cliffs on the west side of Nizina River opposite the mouth of Chitistone River. At this place the Chitistone limestone forms the lower vertical cliffs, which are about 2,000 feet high; the Nizina limestone forms the upper more sloping and uneven cliffs, which are partly covered by talus slopes, and the McCarthy formation forms the smooth slopes above the highest cliffs. The Nizina limestone rests on the Chitistone limestone with apparent conformity and is overlain by the McCarthy formation. The contact with the McCarthy also is apparently conformable in the type section, although there is evidence (see p. 124) of a marked unconformity at other localities. No determinate fossils have yet been obtained from the type section of the Nizina limestone.

In parts of the Kotsina-Kuskulana district, notably in the valley of Elliott Creek and in the hills between Rock and Copper Creeks, the strata occupying the normal position of the Nizina limestone consist of shale that has both the lithologic and the faunal character of the McCarthy shale. This circumstance apparently indicates abrupt variations in the thickness or character of the formation and may be explained either by undetected faults, by rapid changes along the bedding in both lithologic and faunal character, or by a surface of unconformity separating the Nizina limestone from the overlying McCarthy shale. Moffit considers that there is a lateral gradation in the character of the sediments, and that some of these shale beds are the equivalent of the Nizina limestone. The writer believes that so sharp a change from calcareous to argillaceous sediments, affecting a thickness of at least many hundred and possibly several thousand feet of strata and taking place within a horizontal distance of not more than 3 or 4 miles without any evidence of progressive lateral change, is inherently improbable. He finds it easier to believe that these shale beds are the McCarthy shale

brought down into the position of the Nizina limestone by either a fault or an unconformity.

Age and correlation.—The only fossils that have been obtained in the Nizina limestone of the type area consist of one small lot concerning which J. B. Reeside, jr., has submitted the following statement:

11387 (22 F 25). Ridge between McCarthy Creek and East Fork, elevation about 5,900 feet. Near top of Nizina limestone. F. H. Moffit, 1922. Undetermined gastropod.

Inasmuch as these fossils are not characteristic, the determination of the age of the Nizina limestone must be based on its relation to the underlying and overlying formations and on its relations to the rocks of neighboring districts. The Nizina limestone is underlain with apparent conformity by the Chitistone limestone, which is certainly Upper Triassic and probably belongs in the middle or Karnic stage of the Upper Triassic. It is overlain with apparent conformity, but possibly with an actual unconformity, by the McCarthy shale, which is also Upper Triassic and probably belongs in the Upper Noric, near the top of the Upper Triassic.

The Nizina limestone is believed to be represented in the Kotsina and Kuskulana valleys by at least part of the thin-bedded fossiliferous limestone in the lower part of the Kuskulana formation. The known fauna of the lower calcareous portion of the Kuskulana formation, as represented in the following table, was identified from 31 small collections of fossils from localities mostly in the Kuskulana and Kotsina valleys. The complex structure of the Kotsina-Kuskulana district makes it impossible to identify the exact horizons represented by these collections. The fauna appears to be essentially the same as that of the Chitistone limestone. The writer is by no means convinced that some of these collections were not obtained from the Chitistone limestone. A striking difference between this fauna and that of the Chitistone limestone consists in the presence of *Ceratites?* in three collections from the Kuskulana formation. This is probably not a true *Ceratites*, for that genus is supposed to be characteristic of the Middle Triassic.

Fossils from lower part of Kuskulana formation [a]

	9956	8169	8153	8154	8157	8158	8928	8149	8930	8150	8151	8929	8147	9921	9922	9923	9924	9925	9928	9930	9932	9945	9934	9935	9941	9943	8933	8943	8942	8941	8944
Orbiculoidea?																											a				
Pteria?	b																														
Halobia cf. H. superba Mojsisovics														b		b		b	b		b	b								a	a
Halobia cf. H. superba Mojsisovics?				a				a					a							b											
Halobia cf. H. superba (small fine-ribbed form)																	b														
Halobia (with broad ribs)	b																		b				b	b	b						
Halobia		a	a	a		a			a	a	a																		a		
Halobia?					a																					b					
Myophoria?				a																											
Pecten (two or three species)																											a				
Gastropod																								b							
Tropites cf. T. subbullatus Hauer																								b							
Tropites												a																			
Discotropites cf. D. sandlingensis Hauer																								b							
Juvavites (Anatomites) subintermittens Hyatt and Smith																								b							
Juvavites?																								b				a	a		
Ceratites?				a	a	a																									
Arpadites??																								b							
Arcestes																			b					b							
Arcestes?												a			b													a	a		
Undetermined ammonites	b					a	a																			b					
Unidentified organism														b																	

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside, jr.

9956 (F 38). Chokosna River. On ridge northeast of F 37; elevation about 5,200 feet. Dark bluish-gray or black thin-bedded limestone, Triassic. F. H. Moffit, 1916.

8169. Divide between Nugget and Roaring Creeks. Thin-bedded shale. Theodore Chapin, 1912.

8153. Clear Creek. Theodore Chapin, 1912.

8154. Ridge south of Clear Creek. Theodore Chapin, 1912.

8157. First creek south of Clear Creek. Gray limestone. Theodore Chapin, 1912.

8158. Clear Creek. Thin-bedded limestone and shale. Theodore Chapin, 1912.

8928. North fork of Strelna Creek, elevation 3,000 feet. F. H. Moffit, 1914.

8149. North fork of Strelna Creek. Shale area 600 feet south of first large branch on east. F. H. Moffit, 1912.

8930. Left branch of north fork of Strelna Creek, mouth of gulch about 1,400 feet above forks. F. H. Moffit, 1914.

8150. North fork of Strelna Creek, 2,000 feet north of first large branch on east. F. H. Moffit, 1912.

8151. First branch of north fork of Strelna Creek near its mouth. Float. F. H. Moffit, 1912.

8929. 4,700 feet N. 57° E. from forks of north fork of Strelna Creek, elevation 4,000 feet. F. H. Moffit, 1914.

8147. 300 feet above canyon of upper Strelna Creek. F. H. Moffit, 1912.

9921 (F 3). North fork of Strelna Creek, 235 feet upstream from F 2 (where trail to Rock Creek leaves Strelna Creek). Thin-bedded black limestone, dipping about 25° W. About 50 feet stratigraphically below F 2. F. H. Moffit, 1916.

9922 (F 4). North fork of Strelna Creek, 400 feet upstream from F 2. Thin limestone beds, dipping under beds at F 2. F. H. Moffit, 1916.

9923 (F 5). Locality 8, east branch of east fork of Strelna Creek at elevation 4,200 feet. Black shale, argillite, impure limestone, folded and faulted, about 100 feet stratigraphically above exposure of Chitistone limestone. F. H. Moffit, 1916.

9924 (F 6). East branch of east fork of Strelna Creek, upstream from F 5, at elevation 4,300 feet. Calcareous argillite with shale beds. F. H. Moffit, 1916.

9925 (F 7). East branch of east fork of Strelna Creek. Talus between F 8 and F 9. F. H. Moffit, 1916.

9928 (F 10). North branch of east fork of Strelna Creek, elevation 4,250 feet; 4,700 feet southwest of bench mark 6270. Alternating beds of shale and calcareous shale. F. H. Moffit, 1916.

9930 (F 12). On ridge between Dixie Pass branch of Strelna Creek and Clear Creek, 1,500 feet south-southwest of bench mark 6270. Thin shaly limestone. F. H. Moffit, 1916.

9932 (F 14). South brow of round-topped hill on ridge between the east branch of the east fork of Strelna Creek and the small creek between Squaw and Clear Creeks; elevation, 5,500 feet. Black shale and limestone, Triassic. F. H. Moffit, 1916.

9945 (F 27). Dixie Pass branch of Strelna Creek, elevation 4,000 feet. Thin dark limestone. F. H. Moffit, 1916.

9934 (F 16). Locality 566 (1914). West branch of Rock Creek, 2,500 feet. East-northeast of hill 5,350 (map); elevation 4,700 feet. Massive gray shaly limestone 100 feet above exposure of Chitistone; Triassic. F. H. Moffit, 1916.

9935 (F 17). Locality 14. On top of ridge between forks of Rock Creek, 1,500 feet southeast of northwest end of ridge. Limestone beds with shaly partings; Triassic. F. H. Moffit, 1916.

9941 (F 23). Float at base of limestone (Chitistone cliffs) above F 22, which is 3,000 feet northwest by north of Dixie Pass, elevation 4,600 feet. F. H. Moffit, 1916.

9943 (F 25). Locality 22. Gulch tributary to Rock Creek (east fork) from north side, 7,000 feet above forks; elevation 4,500 feet. Thin-bedded limestone and shale. F. H. Moffit, 1916.

8933. Creek entering Kotsina River from north at junction of Kotsina and Kluvesna Rivers, elevation 3,400 feet. F. H. Moffit, 1914.

8943. Outcrop by side of trail at gulch on north side of Kotsina River about 1½ miles below Kluvesna Bridge. G. C. Martin, 1914.

8942. About 10 feet above trail at same locality as 8943. Limestone a few feet above 8943. G. C. Martin, 1914.

8941. About 100 feet above trail at same locality as 8943. Limestone above 8943 and 8942. G. C. Martin, 1914.

8944. Float from same locality as 8943. G. C. Martin, 1914.

CHERT OF FOHLIN CREEK

Chert beds, which have not been described in any of the earlier accounts of this region except for brief mention by Martin [41] and by Moffit and Mertie,[42] are well exposed in the canyon of Fohlin Creek a little over a mile above the mouth of Bear Creek. The outcrops at this point consist of a highly folded and apparently conformable series of beds of chert, limestone, and shale, occurring immediately north of and apparently just below some Upper Jurassic strata. The chert, which is the predominating rock, occurs in the beds 4 to 8 inches thick, separated by very thin strata of shale and by minute partings of indeterminate lithologic character which are probably also shale. The limestone was seen only in a few thin, irregularly distributed strata.

The rocks exposed on the north fork of Fourth of July Creek, from the fork leading to Fourth of July Pass to the greenstone area near the head of the creek, are mostly cherty beds similar to those seen on Fohlin Creek.

No fossils have been found in these chert beds, nor has their relation to the other rocks of the district been determined. They bear a close resemblance to the chert beds in the lower part of the McCarthy formation on Nikolai Creek, as described on page 28, and the writer believes that they are the approximate equivalent of those beds. Beds of shaly limestone containing (see lot 8881, p. 30) *Pseudomonotis subcircularis* (Gabb), the characteristic fossil of the McCarthy shale, crop out on the mountain north of Fourth of July Pass and seem to be in contact with if not interbedded with the

[41] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, p. 690, 1916.

[42] Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, p. 35, 1923.

chert. The same fossil was found (lot 8874, p. 30) in float material on the bank of Fohlin Creek a short distance below the chert outcrops. There is little doubt that the chert beds belong approximately at the horizon of *Pseudomonotis subcircularis*. They bear a striking resemblance to the Kamishak chert of Cook Inlet, described on pages 55–57, the upper part of which is characterized by this same fossil.

In regard to the precise position and relation of these chert beds in the local stratigraphic column there seems to be three plausible interpretations. They may be a distinct local formation occurring between the Nizina limestone and the McCarthy shale, they may be a local sedimentary facies of the lower beds of the McCarthy shale, or they may be the local alteration product of limestone beds. Under either of the first two interpretations their stratigraphic position is clear. Under the third they probably represent thin-bedded limestones which are likely to belong at various horizons in both the McCarthy shale and the Nizina limestone, and probably in the latter formation to a greater extent than in the former, for limestones were originally more abundant there.

The writer believes that beds of chert will probably be found to have a wide distribution in the Chitina Valley. Those here described have hitherto not merely remained unvisited—they have been overlooked, and this may also have occurred at other places. The photographs [43] of crumpled, "thin-bedded limestone" in the Gilahina Valley show a type of folding which is characteristic of the Triassic cherts of Cook Inlet.

McCARTHY FORMATION

Historical review.—The formation named the "McCarthy Creek shales" by Rohn [44] was described as "a series of soft black, highly fissile shales and slates, typically exposed on McCarthy Creek." Most of the rocks which Rohn described [45] as the Kuskulana shales and part of those which he mapped as "unclassified sediments" west of Gilahina River (not those east of it) also belong in this formation.

The McCarthy formation constitutes part of the unnamed upper member of the "Triassic series" or "Triassic shales and limestones" as described by Shrader and Spencer.[46] The rocks thus described

[43] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), pl. 7, 1901. Moffit, F. H., and Maddren, A. G., Mineral resouces of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pl. 4, *A*, 1909.

[44] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 426–427, 431–433, 439–440, pl. 52, 1900.

[45] Idem, pp. 423, 424, 425, 431–432.

[46] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), pp. 33, 46, 47, 1901.

include, however, a great thickness of strata which have recently been determined (see pp. 360–369) as of Upper Cretaceous age. The rocks here referred to the McCarthy formation were described by Schrader and Spencer as follows:

> Above the thin-bedded limestones and sharply defined from them are black shales containing occasional bands of impure limestone, locally affording fossils from which the age of the formation has been determined. The thickness of the upper member of the Triassic is very great, possibly more than 3,000 feet, but no opportunity was afforded for its direct measurement, since its occurrence as the surface formation beneath strata lying unconformably upon it, together with the attitude which it has assumed as the result of folding and faulting, renders its relations complicated and obscure. A few thin flows of greenstone, similar to that of the Nikolai series, were observed here and there interbedded with the black shales of the Triassic. The Triassic series may be easily recognized from its general homogeneous nature and the fine-grained character of its black carbonaceous shales.

Brief mention of these beds under the designation "Triassic shales and limestones" was made by Mendenhall and Schrader[47] and also by Mendenhall.[48] These authors did not attempt to describe this formation in detail, because of the lack of valuable mineral deposits in it.

These rocks were included by Moffit and Maddren[49] as an undifferentiated part of the "Triassic limestones and shales," and as their investigations yielded no new information concerning these beds they quoted in full the description by Schrader and Spencer.

The beds of this formation in the Nizina Valley were mapped and described in detail by Moffit and Capps,[50] who called it the McCarthy shale, restricting the term approximately to Rohn's original usage.

A brief description of the McCarthy formation, chiefly summarized from descriptions by previous observers, was given by Martin.[51]

The occurrence of the McCarthy shale in the upper Chitina Valley has been described briefly by Moffit.[52]

The McCarthy shale is undoubtedly represented in the upper part of the Kuskulana formation of the Kotsina and Kuskulana valleys. The Kuskulana formation was described in detail by Moffit and

[47] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, p. 15, 1903.

[48] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 26, 52, 1905.

[49] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 28–29, 1909.

[50] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 28–30, 1911.

[51] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 690, 695–696, 712, 1916.

[52] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 26–27, pl. 3, 1918.

Mertie,[53] who did not differentiate the McCarthy shale from the underlying thin-bedded limestone.

Stratigraphic description.—The McCarthy formation consists of a conformable succession of shale, chert, and limestone, which overlie the Nizina limestone. It was described by Moffit and Capps as follows:

> The formation as it is exposed in the Nizina district is essentially a shale formation, although at its base are numerous thin limestone beds forming part of the transition zone at the top of the Chitistone limestone or the base of the shale. Thin beds of limestone are found interstratified with the shales wherever they are exposed within the mapped area but are not abundant and form only a small proportion of the whole. The top of the McCarthy shale has not been recognized. Bedding is easily distinguished in most places, either by the presence of the thin limestones or of thin limy shale beds with surfaces highly colored by weathering. Some of the smooth bare hilltops about the eastern tributaries of East Fork are marked with exceedingly intricate patterns produced by the colored beds, for the McCarthy shale is found to be intensely folded wherever it has been examined, and if the folds are cut by planes or curved surfaces making slight angles with their axes the patterns appear.
>
> A thickness of about 1,500 feet of Triassic shale overlies the limestone on the west side of Nizina River. The shales near the center of the broad syncline in this locality have a horizontal position and are probably less distorted by folding than they are to the northwest. This measurement is considered the minimum and probably much less than the true thickness, for some of the shale has certainly been removed by erosion.
>
> The mountains about the head of the East Fork of McCarthy Creek are made up of the black Triassic shales. They reach an altitude of 6,960 feet above sea level or 3,000 feet above the limestone-shale boundary at the creek on the southwest. The shales are much folded about the upper part of the East Fork valley, and measurements are consequently uncertain, but it is probable that the thickness of the formation is at least 2,500 feet in this vicinity. No measurements of value were obtained in the Copper Creek section, for, as previously stated, only a part of the formation is present there.

Although the McCarthy formation has hitherto been described as consisting of shales and limestone, it contains a very considerable amount of black chert, which was not mentioned in most of the earlier descriptions. The position of the chert beds and the general character of the formation on the headwaters of Nikolai Creek are shown in the following section:

Section of part of McCarthy formation on Nikolai Creek

	Feet
Black shale with some chert beds (the fossils of lot 8889 were obtained near the top)	500
Thin-bedded black chert	800
Shale and thin-bedded shaly limestone, with *Pseudomonotis*	200
Concealed to contact with Nizina limestone.	

[53] Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 35–44, pl. 3, 1923.

Age and correlation.—The fauna of the McCarthy formation is small in species but large in numbers. It consists chiefly of *Pseudomonotis subcircularis* (Gabb), which occurs in vast multitudes, making up practically the whole of many beds. Almost no other fossils occur in association with the *Pseudomonotis*, and great thicknesses of strata appear to contain no fossils. *Pseudomonotis subcircularis* is characteristic of the highest beds in the Triassic of California and Nevada. It is very closely related to if not identical with *Pseudomonotis ochotica*, which is the characteristic fossil of the boreal facies of the Noric of Europe and Asia.

The ammonite provisionally identified as *Arniotites?* which was found at three localities high up in the McCarthy formation, does not yield any conclusive evidence on the position of the strata. It may not be an *Arniotites*, and the stratigraphic and biologic position of that genus are none too well established. The genus as originally described was based on forms from British Columbia now believed to be of Upper Triassic (Noric) age, but it possibly includes also a species from the supposed Noric of Japan.

Fossils from the McCarty formation [a]

	9482	6323	6335	6317	13	8889	8890	8891	6311	6314	11379	11381	11382	11388	2200	7	8	8881
Pseudomonotis subcircularis (Gabb)	a	a	a							a				b				
Pseudomonotis subcircularis?				a														
Pseudomonotis															a		a	
Pseudomonotis?					a											a		
Halobia						a					b							
Pecten												b						
Pecten?													b					
Arniotites?						a	a	a										
Undetermined ammonites									a			b						

	9968	9974	8874	6813	9979	11367	11368	2207	2199	9961	9962	9964	11365	9953	9958	9959	1	2
Stems and leaves				c														
Pseudomonotis subcircularis (Gabb)	b	b	a		b	b	b	a	a	b	b	b	b	b	b	b		
Pseudomonotis																	a	a
Hinnites?										b								
Undetermined ammonites										b								

	2202	9947	8156	2206	8160	8162	9931	9926	9920	9936	9937	9938	9939	9940	9944	8945	4804
Coral?									b								
Pseudomonotis subcircularis (Gabb)	a	b		a	a	a	b	b	b	b	b	b	b	b	b	a	a
Pecten					a												
Lima (Plagiostoma)											b						
Undetermined small pelecypods			a														
Halorites cf. H. americanus Hyatt															b		
Juvavites?															b		

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside, jr.; c, identified by F. H. Knowlton.

9482. Streams entering Chitina River at camp 12, about 3 miles above mouth of Canyon Creek, elevation 2,365 feet. Thin-bedded shale and limestone. F. H. Moffit, 1915.

6323. Idaho Gulch near junction with Copper Creek. F. H. Moffit, 1909.

6335. Idaho Gulch about one-third mile above mouth. S. R. Capps, 1909.

6317. Dan Creek about 1⅕ miles below mouth of Copper Creek. F. H. Moffit, 1909.

13. Boulder on flood plain of Nizina River. Oscar Rohn, 1899.

8889. About 100 feet southwest of summit of 6,550-foot peak north of headwaters of Nikolai Creek. Probably 1,500 or 2,000 feet above base of McCarthy formation. G. C. Martin, 1914.

8890. About 0.3 mile southeast of summit of 6,550-foot peak north of headwaters of Nikolai Creek. Nearly the same horizon as 8889. G. C. Martin, 1914.

8891. About 0.2 mile south-southwest of summit of 6,550-foot peak north of headwaters of Nikolai Creek. From nearly the same horizon as 8889. G. C. Martin, 1914.

6311. Mountain north of headwaters of Nikolai Creek, about 1⅔ miles N. 20° E. of Nikolai mine, elevation 6,000 feet. Near the locality and horizon of 8889. F. H. Moffit, 1909.

6314. McCarthy Creek, forks N. 33° E. of Bonanza Peak, elevation 3,850 feet. F. H. Moffit, 1909.

11379 (22 F 18). McCarthy Creek, mouth of third tributary below glacier, on east side. F. H. Moffit, 1922.

11381 (22 F 20). McCarthy Creek, eastern tributary 6 miles north of mouth of East Fork, or 2 miles above Diamond Creek, near mouth of creek. F. H. Moffit, 1922.

11382 (22 F 21). McCarthy Creek, eastern tributary 6 miles north of mouth of East Fork, or about 1½ miles north of Mother Lode camp, south of and 500 feet higher than 22 F 20. F. H. Moffit, 1922.

11388 (22 F 26). Ridge between McCarthy Creek and East Fork, 100 yards north of 22 F 25 and only a short distance above it stratigraphically. F. H. Moffit, 1922.

2200. Float along edge of Kennicott Glacier, 7 miles above Pot Hole. Schrader and Spencer, 1900.

7. West lateral moraine of Kennicott Glacier. Oscar Rohn, 1899.

8. Kennicott Glacier. Oscar Rohn, 1899.

8881. Mountain north of Fourth of July Pass, elevation 4,300 feet, on southeast side. Thin-bedded shaly limestone. G. C. Martin, 1914.

9968 (F 51). Falls of Bear Creek tributary to Fohlin Creek, elevation 3,200 feet. (Float.) F. H. Moffit, 1916.

9974 (F 57). Bear Creek, a quarter of a mile west of Fourth of July Pass and 200 feet higher. Thin-bedded limestone. F. H. Moffit, 1916.

8874. Fohlin Creek about 1 mile above mouth of Bear Creek. Float from east bank of creek. G. C. Martin, 1914.

6813. Fohlin Creek about 1 mile above mouth of Bear Creek. Float from same locality as 8874. G. C. Martin, 1914.

9979 (F 62). Fohlin Creek 12,200 feet north of mouth of Bear Creek. Talus below cliff of thin shale and limy argillite. F. H. Moffit, 1916.

11367 (22 F 4). South side of Lakina River S. 50° W. from mouth of Fohlin Creek, 1,000 feet above Lakina River. F. H. Moffit, 1922.

11368 (22 F 5). South side of Lakina River S. 50° W. from mouth of Fohlin Creek, 1,600 feet above Lakina River. F. H. Moffit, 1922.

2207. West slope of ridge on west side of north fork of Lachina River. Schrader and Spencer, 1900.

2199. Ridge west of north branch of Lachina River, north of triangulation station 75. Schrader and Spencer, 1900.

9961(F 43). Float in gulch below cliff on Mill Creek at locality F 44. F. H. Moffit, 1916.

9962(F 44). Mill Creek, tributary to Lakina River on west side. Shale and thin limestone near forks of creek, 2½ miles from Lakina River. F. H. Moffit, 1916.

9964(F 46). Mill Creek, north fork, 1 mile north of mouth. F. H. Moffit, 1916.

11365(22 F 2). Ridge south of west branch of Lakina River, 800 feet higher than little lake south of trail. F. H. Moffit, 1922.

9953(F 36). One mile south of mouth of creek that comes down from Kuskulana Pass into Chokosna River. Thin shale and limestone. F. H. Moffit, 1916.

9958(F 40). Chokosna River, 1 mile southeast of mouth of creek flowing from Kuskulana Pass. Shale and thin limestone. F. H. Moffit, 1916.

9959(F 41). Chokosna River, about 1½ miles southeast of mouth of creek flowing from Kuskulana Pass. Thin-bedded shale and limestone. F. H. Moffit, 1916.

1. West side of Kuskulana River. Oscar Rohn, 1899.

2. West side of Kuskulana River, a short distance north of No. 1. Oscar Rohn, 1899.

2202. Creek on north side of Kuskulana River, near camp 16. A. C. Spencer, 1900.

9947(F 29). Squaw Creek, elevation 3,100 feet. Dark limestone in beds as much as 2 feet thick. F. H. Moffit, 1916.

8156. First creek south of Clear Creek. Black calcareous shale. Theodore Chapin, 1912.

2206. Head of Rock Creek. Black slaty limestone in thin-bedded limestone and slate series. F. C. Schrader, 1900.

8160. Divide between Clear Creek and Rock Creek, ridge east of Dixie Pass, elevation 6,100 feet. Theodore Chapin, 1912.

8162. Divide between Clear Creek and Rock Creek, trail on ridge south of 6,270-foot peak, elevation 6,100 feet. Theodore Chapin, 1912.

9931(F 13). Ridge 200 feet north of F 12 (on ridge between Dixie Pass branch of Strelna Creek and Clear Creek, 1,500 feet south-southwest of bench mark 3270). F. H. Moffit, 1916.

9926(F 8). Locality 9. East branch of east fork of Strelna Creek; elevation 5,200 feet; 5,000 feet south of bench mark 6270. Alternating beds of soft shale and calcareous limestone. F. H. Moffit, 1916.

9920(F 2). North fork of Strelna Creek where trail to Rock Creek leaves Strelna Creek. Thin shale and limestone dipping about 20° W. F. H. Moffit, 1916.

9936 (F 18). Gulch leading from west branch of Rock Creek to saddle between Rock Creek and East Fork of Copper Creek. *Pseudomonotis* common in float of this gulch up to elevation 5,200 feet, above which talus is all very fine. F. H. Moffit, 1916.

9937 (F 19). Highest point of ridge between East Fork of Copper Creek, Pass Creek, and Rock Creek. Zone of shaly limestone, 8 to 10 feet thick, with abundant *Pseudomonotis*. F. H. Moffit, 1916.

9938 (F 20). Locality 18, on west branch of Rock Creek, 2,200 feet from forks, 150 feet northeast of exposure of Chitistone limestone. Alternating shale and calcareous shale or argillite. F. H. Moffit, 1916.

9939 (F 21). West branch of Rock Creek, 400 feet from mouth. Alternating shale and hard argillite beds. F. H. Moffit, 1916.

9940 (F 22). Locality 19, 3,000 feet northwest by north of Dixie Pass, elevation 4,600 feet; 200 feet below outcrops of Chitistone limestone. Hard brown-weathering limestone or calcareous shale. F. H. Moffit, 1916.

9944 (F 26). Gulch tributary to east branch of Rock Creek from north side, 200 feet from east branch. Thin shale and limestone or calcareous shale. F. H. Moffit, 1916.

8945. Rock Creek, elevation 3,475 feet. G. C. Martin, 1914.

4804. Magpie Creek, 1 mile above junction with Elliott Creek. F. H. Moffit, 1907.

NABESNA-WHITE RIVER DISTRICT

GENERAL FEATURES

A well-defined although probably discontinuous belt of Triassic rocks extends through the southern foothills of the Nutzotin and Alaska ranges from the vicinity of the Canadian boundary to the headwaters of Susitna River. The eastern part of this belt, which is known as the Nabesna-White River district, lies north of the Chitina Valley and is separated from it by the Wrangell Mountains, in which the Quaternary and late Tertiary lavas and the existing glaciers conceal the underlying Mesozoic strata. Because of this lack of continuity and because of differences in the character of the sediments, the rocks in the two districts are somewhat difficult of correlation. The probable sequence of strata in the Nabesna-White River district has been indicated by Moffit and Knopf [54] in the following table:

Quaternary	Gravels, till, and other unconsolidated deposits.
Tertiary	Volcanic rocks. Lignite-bearing formation, including shales, sandstones, lignite beds, etc.
Jurassic	Shales of Jacksina Creek. Shales, slates, and graywackes of the Nutzotin Mountains.
Triassic	Thin-bedded limestone of Cooper Creek.
Carboniferous or later	Lavas and pyroclastic beds—tuffs, volcanic breccias, etc. Shales of Skolai Pass.
Carboniferous	Massive limestone. Shales with some tuffs and lava flows. Basic lavas and pyroclastic beds, with some shale and limestone beds.

[54] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 16, 1910.

SHALE AND VOLCANIC ROCKS

Historical review.—The "shales of Skolai Pass" and the "lavas and pyroclastic beds," both of which are classed in the above table as "Carboniferous or later," are at least in part of Triassic age. They include part of the rocks seen by Hayes[55] at Skolai Pass and described by him as including "red sandstone and jasper and a great thickness of black shale." They include part of the rocks mapped by Brooks[56] as the "Nutzotin series" and as the "effusive series," but the parts of these aggregates that are now known to be of Triassic age were not described specifically. These rocks also include a portion of the rocks described and mapped by Rohn[57] as the "Skolai volcanics." They comprise an apparently large part of the "Diabasic series" described by Mendenhall and Schrader[58] from the field observations of Schrader.

These rocks were described by Moffit and Knopf[59] under the heading "Carboniferous," with the qualification that this assignment was provisional, and they were represented on the geologic map,[60] together with the shales and volcanic beds beneath the Carboniferous limestone, as "undifferentiated Carboniferous rocks, possibly also including some rocks of Mesozoic age." The failure to separate the Triassic and Carboniferous rocks was due partly to the lithologic similarity of the Triassic shale, lava, and tuff to the sedimentary and volcanic beds beneath the Carboniferous limestone, partly to the scarcity of fossils, and partly to the complex structure.

These rocks are also an undifferentiated part of those which Capps[61] described and mapped as "mainly Carboniferous lava flows, tuffs, and agglomerates." Capps did not specifically describe any rocks that are known to be Triassic, but he stated that "within the areas composed predominantly of Carboniferous rocks there are minor amounts of beds of both older and younger formations." He also mentioned[62] the occurrence on the Middle Fork of White River (see p. 35) of Triassic fossils which he erroneously referred to as "Jurassic."

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[55] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, p. 140, 1892.

[56] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana rivers: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 359–360, 362–363, pl. 47, 1900.

[57] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 429–430, pl. 52, 1900.

[58] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, pp. 35–36, 1903.

[59] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, pp. 17–27, 1910.

[60] Idem, pl. 2.

[61] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 30, 33–47, pl. 2, 1916.

[62] Idem, p. 34.

The writer believes that the "lavas and pyroclastic beds with some shales" which constitute the upper member of the Carboniferous section of Capps[63] may prove to be post-Carboniferous, as was suggested by Moffit and Knopf.[64] Evidence in favor of the assignment of these rocks to the Triassic is given by the Triassic fossils from the volcanic breccia on the Middle Fork of White River. The "distorted argillites and cherts" which Capps[65] mentions as occurring near the mouth of Beaver Creek, and which he "provisionally included with the Carboniferous," are suggestive of some of the Triassic rocks of other regions.

Stratigraphic description.—The massive Carboniferous limestone of Skolai Pass and vicinity is overlain by shale, above which is a great thickness of lava, tuff, and breccia. These beds, because of their association and apparent conformity with the Carboniferous limestone, were provisionally assigned to the Carboniferous by Moffit and Knopf. The shales which immediately overlie the limestone in Skolai Pass were described by Moffit and Knopf[66] as being nearly 300 feet thick, as containing interbedded tuffs in their upper part, and as being barren of fossils. Characteristic Upper Triassic fossils were, however, found at this locality by Hayes,[67] who described the occurrence as follows:

> In the walls of Skolai Pass, by which the range is crossed, its stratigraphy and structure are magnificently displayed. The rocks are comparatively recent, for the most part Carboniferous, Triassic, and Cretaceous. A bed of limestone about 500 feet thick contains many crinoids and corals, probably of Carboniferous age. Above it are red sandstone and jasper and a great thickness of black shale. Collections of fossils from the limestone and the black shale were made, but before reaching the coast they unfortunately were lost, with the exception of a single small piece of shale; this, however, contained several tolerably perfect impressions and was submitted to Prof. Alpheus Hyatt for identification. He says: "The fossils in the shale are clearly the remains of a *Monotis* [*Pseudomonotis*] of a Triassic type, allied to *M. subcircularis*, Gabb, a characteristic Triassic form in California. This one seems to be distinct specifically, but is evidently of the same age.

Age and correlation.—The presence of *Pseudomonotis subcircularis* in the shales of Skolai Pass indicates that these rocks are to be assigned to the same general position as the McCarthy formation of the Chitina Valley. The pyroclastic beds of the north front of

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[63] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 39, 1916.

[64] Moffit, F. H., and Knopf, Adolph, op. cit., p. 16.

[65] Capps, S. R., op. cit., pp. 35–36.

[66] Moffit, F. H., and Knopf, Adolph, op. cit., p. 17.

[67] Hayes, C. W., An expedition through the Yukon district: Nat. Geog. Mag., vol. 4, p. 140, 1892.

the Wrangell Mountains, which probably overlie the shale of Skolai Pass, have also yielded Upper Triassic fossils as listed below. These fossils were collected by A. Neustaedter and are said to have been obtained from a volcanic breccia, but the locality has never been visited by a geologist, so it is impossible to describe the occurrence in detail. They were identified as follows by T. W. Stanton, according to whom the *Clionites* "is a characteristic Upper Triassic type of ammonite."

8479. About 3 miles from foot of glacier on Middle Fork of White River, in a southerly direction and about 800 feet above the river:

Pseudomonotis subcircularis (Gabb)?
Clionites (Shastites) sp.

The correlation of the Upper Triassic shale, tuff, and lava of the Nabesna-White River district with the rocks of other districts involves serious difficulties. These rocks carry the fauna of the McCarthy formation of the Chitina Valley, but that formation contains no volcanic material. A correlation of these beds with the Nikolai greenstone of the Chitina Valley has been suggested by Moffit and Maddren,[68] by Moffit and Knopf,[69] and by Moffit and Capps.[70] This correlation seemed highly probable as long as there were grounds for believing that both formations belong in the interval between the Carboniferous limestone of White River and the Chitistone limestone of the Chitina Valley. The Nikolai greenstone is, however, certainly older than the Chitistone limestone, which it clearly underlies, and is probably older than Upper Triassic, possibly being upper Carboniferous, whereas the Triassic shale, tuff, and lava of White River and Skolai Pass include beds that carry a fauna younger than that of the Chitistone limestone. It is consequently clear that these volcanic rocks can not be correlated with the Nikolai greenstone.

The apparent absence of any Triassic rocks in the Nabesna-White River district that can be correlated with either the Nikolai greenstone or the Chitistone limestone indicates that there is profound unconformity between the Carboniferous limestone and the overlying Upper Triassic *Pseudomonotis*-bearing beds. No physical evidence of this unconformity has yet been found, but the absence of detailed stratigraphic data and the known complexity of the structure make it impossible to say that because the unconformity has

[68] Moffit, F. H., and Maddren, A. G. Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, p. 24, 1909.

[69] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 26, 1910.

[70] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 63, 1911.

not been seen it probably does not exist. The irregular distribution of the upper Carboniferous limestone beds is in itself a possible indication of a post-Carboniferous unconformity. The writer believes that extreme lenticularity in a limestone bed is inherently a highly improbable original feature, and he is consequently inclined to assert that the irregular distribution of the upper Carboniferous limestone is almost certain proof that the original continuity of the limestone has been destroyed either by erosion or by structural disturbances.

There is evidence that an unconformity may be present (see p. 124) at the base of the McCarthy formation in the western part of the Chitina Valley. This unconformity agrees in stratigraphic position with the hypothetical unconformity now being considered.

LIMESTONE AND SHALE OF COOPER PASS

Historical review.—The Triassic rocks in the vicinity of Cooper Pass, on the south front of the Nutzotin Mountains between Chisana and Nabesna Rivers, were first recognized by Schrader and were mentioned briefly by Mendenhall and Schrader,[71] in a report on the mineral resources of this district, as part of the "Mesozoic series." Mendenhall[72] also made brief mention of these rocks in a discussion of the age of the Chitistone limestone. A brief account of the occurrence and character of the Triassic limestone of Cooper Pass was given by Moffit and Knopf.[73] The occurrence and correlation of this limestone have been discussed briefly by Capps[74] and by Martin.[75]

Stratigraphic description.—The Triassic rocks of Cooper Pass were described by Moffit and Knopf[76] as consisting of a single limestone formation that occurs in close geographic and structural association with a massive Carboniferous limestone. The Triassic and Carboniferous limestones are not easily distinguished, except by their faunas. The Triassic limestone is more thinly bedded than the Carboniferous limestone. It has been so much faulted and cut by dikes that neither its thickness nor its relations to the associated formations have been determined, but its thickness is apparently

[71] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, pp. 36–37, 1903.

[72] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 49–50, 1905.

[73] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, pp. 27–32, 1910.

[74] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 29, 30, 47–53, 1916.

[75] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, p. 696, 1916.

[76] Moffit, F. H., and Knopf, Adolph, op. cit., pp. 27–28.

much less than that of the Carboniferous limestone. Mendenhall[77] described the Triassic rocks of Cooper Pass, from Schrader's observations, as "consisting of black shales and dark limestones closely resembling the thin-bedded dark limestones that are above the Chitistone limestone in the Chitina Valley."

Age and correlation.—The fauna of the Triassic rocks of Cooper Pass, as now known, is represented by the fossils from the localities listed below, identified by T. W. Stanton. Fossils were seen also at the mouth of Wilson Creek, but no collections were made at that locality, for the fossils show only on the weathered surface of the rocks and it is difficult to procure good specimens. The age of the limestone on Wilson Creek, consequently, is more or less doubtful.

1454.[1] Round Mountain, northeast of Cooper Pass. Triangulation station No. 27. F. C. Schrader, 1902. *Pseudomonotis.*

5721. Limestone between the forks of Cooper Creek. Moffit and Knopf, 1910. *Pseudomonotis subcircularis* (Gabb).

5724. Cooper Pass. Moffit and Knopf, 1910. *Pseudomonotis subcircularis* (Gabb).

The Upper Triassic limestone of Cooper Pass bears some resemblance to the Chitistone limestone, with which Moffit and Knopf suggested a correlation. It differs from the Chitistone limestone in being far thinner, in being more thinly bedded, and in carrying a younger fauna. In its lithologic character it bears closer resemblance to the limestone at the base of the McCarthy formation, and as it carries the fauna of the McCarthy formation it may be assigned to that horizon.

UPPER SUSITNA VALLEY

GENERAL FEATURES

A belt of Triassic rocks extends through the foothills south of the Alaska Range from the headwaters of Gulkana River to a point west of Susitna River. This belt lies in a geographic and structural position similar to that of the Triassic rocks south of the Nutzotin Mountains and should probably be regarded as their western discontinuous extension. The Triassic rocks south of the Alaska Range include fossiliferous Upper Triassic limestone and a group of slate, tuff, arkose, calcareous sandstone, and limestone that are closely associated with and probably overlie the fossiliferous limestone. The latter is underlain by basic lava and tuff that seem to rest on a Carboniferous (?) limestone and that consequently correspond in

[77] Mendenhall, W. C., op. cit., p. 50.

stratigraphic position, as well as in lithologic character, to the Nikolai greenstone of the Chitina Valley and should probably be assigned to the Permian or early Triassic.

The Triassic beds and the rocks most intimately associated with them in the belt between Gulkana and Susitna Rivers were described by Moffit[78] as including (*a*) Carboniferous or Triassic lavas; (*b*) fossiliferous Upper Triassic limestone; (*c*) slate, tuff, arkose, calcareous sandstone, and limestone, all closely associated with and probably overlying the fossiliferous Upper Triassic limestone; and (*d*) highly metamorphosed schist that may be the altered representative of the Triassic rocks. The extension of this belt west of the Susitna River was described by Moffit[79] as including "Triassic or Carboniferous (?) basic lava flows with tuff beds [the extension of *a* above]; Upper Triassic (?) slate, with intercalated beds of graywacke, arkose, etc. [the extension of *c* and part of *d*]; and undifferentiated Mesozoic (?) slates, argillites, graywacke, and thin-bedded limestone [the extension of *d* in part]." A further southwest extension of this belt was mapped by Chapin,[80] who described "Triassic (?) lavas and tuffs" and "Upper Triassic (?) slate, graywacke, limestone, and schist," and by Capps,[81] who described some "possibly Triassic" limestone, marble, shale, slate, and quartzite in the western Talkeetna Mountains. The possible northeast extension of this belt into the Chistochina district is suggested by an ammonite which is said to have been found on Slate Creek.

BASIC LAVAS AND TUFFS

Historical review.—The Upper Triassic limestone of the upper Susitna Valley, described below, is apparently underlain by Triassic or Carboniferous volcanic rocks that cover large areas in the southern foothills of the Alaska Range.

These rocks were first observed on the headwaters of Gulkana River, in the vicinity of Tangle Lakes, by W. C. Mendenhall in 1898. Mendenhall was making a rapid exploratory journey and had no opportunity to study or describe the rocks in detail. These rocks apparently constitute the "acid effusives and associated rocks" and possibly also part of the "greenstone series" as described by Mendenhall.[82]

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[78] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, pp. 22, 29–33, pl. 2, 1912.

[79] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, 1915, pp. 24, 26–31, pl. 2.

[80] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 21, 26–28, pl. 2, 1918.

[81] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, p. 195, 1919.

[82] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 311–313, 1900.

The occurrence of these volcanic beds in the area between Gulkana and Susitna rivers has been noted by Moffit, these rocks constituting the "basic lavas and tuffs" as described in the text[83] and the "amygdaloidal lava flows with intercalated tuffaceous and shaly beds" as represented on the map.[84] Moffit considered these beds probably either late Carboniferous or early or Middle Triassic, and probably approximately synchronous with the Nikolai greenstone. The western extensions of these rocks in the hills west of Susitna River were described by Moffit[85] as "Triassic (?) lavas" and by Chapin[86] as "Triassic (?) lavas and tuffs."

Character and age.—The lava and tuff of the area between Gulkana and Susitna Rivers were described by Moffit as follows:

These rocks consist largely of diabase and locally are amygdaloidal, showing that in part, at least, they are surface lava flows. They are associated with argillites, tuffs, and tuffaceous conglomerates in a number of places and are intruded by diabases and by dikes of less basic, light-colored porphyritic rock.

The extension of these rocks west of Susitna River was described by Moffit as consisting principally of basaltic lava flows with associated andesitic flows and water-laid tuffaceous beds. The estimated thickness is 3,500 feet.

The volcanic rocks of the upper Susitna Valley apparently underlie the Upper Triassic limestone and are believed to rest upon an upper Carboniferous limestone. They thus correspond approximately in stratigraphic position, as well as in lithologic character, with some of the late Carboniferous volcanic rocks of the Nabesna-White River district, or with the Nikolai greenstone.

LIMESTONE

Fossiliferous Triassic limestone occurs in several small areas in the foothills of the Alaska Range between Maclaren and Susitna Rivers. This limestone constitutes an undifferentiated part of the "Triassic rocks" as described by Moffit,[87] and is the "Triassic limestone" as represented on his geologic map.[88]

This limestone crops out in a series of small detached areas lying in a belt between Maclaren and Susitna Rivers but mostly in the val-

[83] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, pp. 22, 29–30, 1912.

[84] Idem, pl. 2.

[85] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 24, 26–28, 1915.

[86] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 21, 26–27, 1918.

[87] Moffit, F. H., Headwater regions of Gulkana and Susitna rivers, Alaska: U. S. Geol. Survey Bull. 498, pp. 22, 31, 33, 1912.

[88] Idem, pl. 2.

ley of Clearwater Creek. The discontinuity of the outcrops is probably due to structural disturbances rather than to original lenticularity. Several of these limestone masses rest directly upon the amygdaloidal lava flows described on pages 38–39, and all of them are not far from the main area of the volcanic rocks. The limestone, which apparently can not be more than a few hundred feet thick, is overlain by the Upper Triassic slate, tuff, arkose, and calcareous beds described on pages 40–42.

The fauna of this limestone, as at present known, is represented by the fossils enumerated in the following list, which were identified by T. W. Stanton. These fossils were obtained from bluish-gray limestone beds that rest upon the volcanic rocks.

6570. Limestone area on a small western tributary of Clearwater Creek:
- Halobia sp. related to H. superba Mojsisovics.
- Tropites sp.
- Discotropites? sp.
- Arcestes sp.

This fauna appears to be essentially identical with that of the Chitistone limestone of the Chitina Valley. The equivalence of this limestone with part of the Chitistone limestone is also indicated by the facts that it rests directly upon the volcanic rocks and that, like the Chitistone limestone, it is apparently overlain by beds carrying *Pseudomonotis subcircularis* (Gabb). It consequently is presumably low in the local Upper Triassic sequence.

SLATE, TUFF, ARKOSE, AND CALCAREOUS BEDS

Historical review.—The Triassic slate, tuff, arkose, and calcareous beds of the upper Susitna Valley occur in a belt that extends through the southern foothills of the Alaska Range from Maclaren Glacier into the hills west of Susitna River. The limestone described on pages 39–40 occurs along the southern border of these rocks and presumably underlies them.

The rocks of the eastern part of this belt, from Maclaren Glacier to Susitna River, were mapped by Moffit[89] as " Upper Triassic slates, tuffs, arkose, calcareous sandstones, and limestones, with some diorite and diabase intrusives," and were described in his text[90] as " Triassic rocks "; that heading included also the Upper Triassic limestone that is discussed on pages 39–40 and some highly metamorphosed schist that may be the altered representative of the Triassic rocks, but was mapped as distinct from them.

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[89] Moffit, F. H., Headwater regions of Gulkana and Susitna Rivers, Alaska: U. S. Geol. Survey Bull. 498, pl. 2, 1912.

[90] Idem, pp. 22, 31–33.

The rocks of that part of the belt lying west of Susitna River were discussed by Moffit[91] under the heading "Triassic sediments." They apparently include only the rocks here under consideration, the limestone being absent, and the metamorphic rocks being mapped and described separately.

There is a possible extension of these rocks farther southwest, on the west side of Tsisi Creek between Susitna and Talkeetna Rivers, where Chapin[92] noted some "Upper Triassic (?) slate, argillite, and graywacke with some thin beds of limestone," and in the valleys of Iron Creek and Sheep River in the western Talkeetna Mountains, where Capps[93] noted some "limestone, marble, shale, slate, and quartzite" that are possibly Triassic.

Stratigraphic description.—The Upper Triassic slate, tuff, arkose, and calcareous beds of the belt that extends northeastward from Susitna River between Valdez and Windy Creeks to Maclaren Glacier were described by Moffit as being but little metamorphosed and as including banded slate, black slate, red-weathering slate or shale, graywacke or fin tuff, tuffaceous conglomerates, diabase flows or intrusions, shaly limestone, and calcareous sandstone. The thickness has not been determined but is probably many hundred if not several thousand feet.

The rocks of the extension of this belt to the west of Susitna River were described by Moffit as including dark-blue and black slate, with interstratified beds of arkose and graywacke, probably several thousand feet thick. These rocks are closely folded and show a varying degree of metamorphism that has locally changed the argillite and arkose to phyllite and schist.

The "undifferentiated Mesozoic (?)" slate, argillite, graywacke, and thin-bedded limestone on the headwaters of Susitna River may or may not include Triassic rocks. They were described by Moffit as comprising "a complex of beds that could not be differentiated in the time available." Moffit said of them:

> The age of these sediments is unknown. It is perhaps possible but does not appear probable that they may correspond in part with some of the Devonian formations. On the other hand it seems much more likely that they are of Mesozoic age and are to be correlated with the Triassic slates and limestones of the Valdez Creek district or with the Jurassic (?) sediments of Jack River. It may even be that they include beds belonging to both of these groups.

The supposed Triassic rocks between Susitna and Talkeetna rivers were described by Chapin as consisting of limestone, slate, argil-

[91] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 24, 29–31, 1915.

[92] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 27–28, pl. 2, 1918.

[93] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, p. 195, 1919.

lite, and related coarser sediments as well as dioritic and other intrusive rocks. The most prominent members are dark-blue and black slate and argillite and greenish-gray graywacke. Thin beds of crystalline limestone are intercalated with the other sediments. A section on a tributary of Tsisi Creek indicates that the thickness is at least 2,000 feet and may be much greater, for neither top or bottom was seen. These rocks have yielded no fossils. Chapin referred them tentatively to the Triassic because they lie on the strike of the Triassic rocks southeast of Valdez Creek and bear some resemblance to those rocks.

The supposed Triassic rocks of the western Talkeetna Mountains were described by Capps as including a massive limestone at least 600 feet thick, in some places overlain by a considerable thickness of shale slate, and quartzite. These rocks have yielded no fossils. They are apparently overlain by volcanic rocks that are believed to be Lower Jurassic.

Age and correlation.—The slate, tuff, arkose, and calcareous beds of the upper Susitna Valley apparently overlie the limestone just described. They contain *Pseudomonotis subcircularis* (Gabb), which, together with the position of the rocks relative to the underlying limestone, indicates that they belong in the same general position as the McCarthy formation. The rocks associated with the fossilferous beds, however, are strikingly unlike those of the McCarthy formation, which consist of shale, chert, and limestone, with no beds of tuff or arkose. The formation as a whole, both in its lithologic and in its faunal character, bears a strong resemblance to the Upper Triassic limestones and tuffs of Port Graham, described on pages 49–51, and to the Triassic volcanic beds of Skolai Pass, described on pages 33–36, both of which contain this same fossil.

The fossils obtained at the localities listed below were identified by T. W. Stanton.

6571. Coal Creek, a tributary of Clearwater Creek, 15 miles east of Susitna River. Exposure showing several hundred feet of thin-bedded shaly limestone and calcareous sandstone. Their position within the formation has not been determined but is probably considerably above the base. F. H. Moffit, 1910. *Pseudomonotis subcircularis* (Gabb).

6572. West of Clearwater Creek, about 2 miles northwest of the locality from which No. 5670 was taken. Limestone bed of indeterminate position. F. H. Moffit, 1910. *Serpula.*

CHULITNA VALLEY

GENERAL FEATURES

Upper Triassic rocks are known in two areas in the Chulitna Valley. One of these areas lies in the foothills of the Alaska Range on several of the western tributaries of the West Fork of the Chu-

litna. The other area lies on eastern tributaries of the East Fork of the Chulitna. The two areas are not parts of the same structural belt but occur in two distinct and apparently parallel belts that are 10 miles or more apart at the nearest place and are separated by areas of pre-Triassic igneous and metamorphic rocks and by the alluvial filling of the main Chulitna Valley.

The Triassic rocks west of Chulitna River consist chiefly of tuff, limestone, shale, and lava. They rest unconformably on greenstones and metamorphic sedimentary rocks that are believed to be pre-Triassic. They are apparently overlain by argillite, slate, and graywacke that may be Jurassic or Cretaceous. They contain a fauna that certainly is Triassic but is different from most of the Upper Triassic faunas of Alaska, though it has some resemblance to the Triassic fauna of Gravina Island.

The Triassic rocks east of Chulitna River consist chiefly of thin-bedded limestone and shale. The character and relations of the underlying and overlying rocks are not known. They carry the well-known *Pseudomonotis* fauna.

TUFF, LIMESTONE, SHALE, AND LAVA OF WEST FORK

Stratigraphic description.—The Triassic tuff, limestone, shale, and lava of the West Fork of Chulitna River were described by Capps [94] substantially as follows:

Triassic tuff, limestone, shale, and basic lava flows, with minor amounts of conglomerate and graywacke, apparently lie unconformably upon the underlying greenstone, tuff, slate, and chert. On Ohio Creek an excellent section is exhibited. There the older group of tuff, slate, and chert appears to lie unconformably beneath a heavy bed of conspicuous red tuff and agglomerate. This red tuff is the basal member of a group of rocks that has an aggregate thickness of several thousand feet and includes tuff, agglomerate, conglomerate, amygdaloidal greenstone flows, and massive limestone beds. The tuffs range in texture from fine-grained rocks that resemble red sandstone to coarse agglomerates containing fragments of volcanic débris several inches across. They range in color from vivid red, in which the composing fragments are chiefly jaspilite, through green and purple shades. In some of the tuffs the fragments all appear to be sharply angular; in others partly rounded. These tuffs grade into conglomerates. On upper Ohio Creek there are five massive limestones. One of these yielded fossils of Triassic age, and other fossils from boulders in Copeland Creek appear to be of the same age. The tuff beds so abundant in the lower rocks give place

[94] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 216–217, 1919.

higher up to amygdaloidal lava flows, and on Ohio Creek a considerable thickness of lava appears above the uppermost limestone.

The section on West Fork of Chulitna River, though presenting certain features in common with that on Ohio Creek, is greatly different in detail. The red and green tuffs are present at the base. The abundant intrusive dikes and sills have altered the surrounding rocks, and as a result the limestone, here inconspicuous, is generally changed to marble, and white, cream-colored, and bluish cherts appear. The amygdaloidal greenstone so abundant on Ohio Creek is relatively scarce on West Fork of Chulitna River, where the group is overlain by a heavy body of black argillite, slate, and graywacke.

Age and correlation.—The Triassic rocks of the West Fork of Chulitna River differ both in their stratigraphic sequence and in their fauna from most of the other Triassic rocks of Alaska. The fauna does not include any of the common fossils such as *Halobia*, *Pseudomonotis*, or the ammonites which are characteristic of the well-known horizons in the Upper Triassic of Alaska. T. W. Stanton, who determined the fossils listed in the following table, stated that the presence of *Cassianella* in these collections suggests the Triassic fauna of Gravina Island, in southeastern Alaska."

Fossils from West Fork of Chulitna River [a]

	10090	10091	10092	10093	10094
Terebratula	×	×	×	×	
Avicula				×	×
Cassianella				×	×
Myophoria??				×	
Aviculipecten?			×		
Pecten	×		×		
Pecten?			×		
Lima				×	
Lima?		×			
Astarte?		×			
Undularia?					×
Loxonema (Anoptychia)?				×	
Loxonema?				×	
Coelostylina?				×	×

[a] Identified by T. W. Stanton.

10090–10093 (Nos. 1–4). Stream bar of Copeland Creek. S. R. Capps, 1917.

10094 (No. 5). Talus below limestone outcrop on Ohio Creek 1½ miles above mouth of Christy Creek. S. R. Capps, 1917.

LIMESTONE AND SHALE OF EAST FORK

The Upper Triassic limestone and shale of the East Fork of Chulitna River were discovered by R. M. Overbeck in 1919 but have not yet been described. They consist, according to Overbeck's field notes, of rather thin bedded, much crushed and folded bluish slate and limestone. He mentions the presence of graywacke and chert near the localities that yielded the Triassic fossils but does

not state their relation to the fossiliferous beds. No information is available concerning the thickness of the Triassic rocks or the character and relations of the underlying and overlying beds.

The fossils that have been found in the Upper Triassic limestone and shale of the East Fork of Chulitna River were identified by T. W. Stanton and are listed below. The presence of *Pseudomonotis subcircularis* as well as the character of the rocks indicates a correlation with the McCarthy shale and with the *Pseudomonotis*-bearing beds of other Alaskan districts. Concerning the coral *Heterastridium*, which has been found elsewhere in Alaska only in the limestone of Iliamna Lake (see p. 60), Stanton said: "This genus of hydroid coral is characteristic of the Upper Triassic in the Alps and in India."

10241 (F 4). East Fork of Chulitna River, south side, 1½ miles below camp 9. R. M. Overbeck, 1919. *Heterastridium.*

10242 (F 2). Creek entering East Fork below camp 9, upper Chulitna Valley. R. M. Overbeck, 1919. *Pseudomonotis subcircularis* (Gabb).

10243 (F 3). Same locality as F 2. R. M. Overbeck, 1919. *Heterastridium.*

KENAI PENINSULA

GENERAL FEATURES

The Triassic rocks of the east coast of Cook Inlet occur at the southwest end of Kenai Peninsula, in a belt that extends northeastward from Port Graham parallel to the south shore of Kachemak Bay. They include limestone and tuff with Upper Triassic fossils, apparently underlain by contorted chert which has yielded no characteristic fossils but which the writer believes to be Upper Triassic. Beneath the chert is ellipsoidal lava, which is underlain by slate and graywacke. The Upper Triassic limestone and tuff are overlain, probably unconformably, by Lower Jurassic tuff and agglomerate. The probable sequence of formations is indicated in the following table:

General section of Mesozoic rocks in Kenai Peninsula

Lower Jurassic: Tuff and agglomerate with Lower Jurassic fossils.
Upper Triassic:
  Limestone and tuff with Upper Triassic fossils.
  Contorted chert.
Triassic or Carboniferous: Ellipsoidal lava.
Paleozoic (?): Slate and graywacke.

ELLIPSOIDAL LAVA

Historical review.—The first published description of the ellipsoidal lava of the Kenai Peninsula was a brief note on the spheroidal

diabase of Halibut Cove by Emerson.[95] A more complete description of the lava observed at different places along the coast from Seldovia Bay to Aurora was given by Moffit,[96] who described the rocks as pre-Jurassic diabase. Brief mention of the occurrence of ellipsoidal greenstone was made by Grant and Higgins[97] in their preliminary report on the ore deposits of this district, but they did not attempt to describe the rocks in detail. The lava of the entire belt has been described and mapped by Martin[98] as "Triassic (?) ellipsoidal lavas."

Character, stratigraphic position, and age.—Ellipsoidal lava is widely distributed in the parts of Kenai Peninsula that border on the south shore of Kachemak Bay and on the extreme southern part of Cook Inlet. Exposures are abundant along a probably discontinuous series of belts extending from Port Graham at least as far northeastward as Aurora, but the best exposures are on Port Graham, Seldovia Bay, Hesketh and Yukon Islands, and Halibut Cove.

The ellipsoidal lava of Kenai Peninsula consists predominantly of green scoriaceous and ellipsoidal lava, interbedded with a small amount of tuff. At a few places, notably on Hesketh and Yukon Islands, the color is dark red rather than green. The lava is well displayed in the cliffs on the east shore of Seldovia Bay, where the exposures begin at a point almost 2 miles below the head of the bay and extend as far north as the end of the cape just above the cannery. These exposures consist of greenish ellipsoidal and scoriaceous basalt containing veins and irregular masses of epidote. A little chert is interbedded with the lava. The thickness of these rocks, as computed from the width of the belt and the average dip on the shores of Seldovia Bay, on the assumption that there is no repetition by faulting, is about 3,000 feet.

The stratigraphic relations of the lava to the underlying and overlying rocks are shown most clearly on Seldovia Bay. The excellent exposures on the east shore of the bay show that the lava is underlain by slate, graywacke, crumpled chert, and some volcanic rocks. aggregating over 5,000 feet in thickness. The dip of the slate and other rocks places them beneath the lava, but there is no conclusive evidence as to whether or not the contact is conformable. The lava is, however, considerably less altered than the volcanic members of the slate and graywacke series, and it is consequently assumed to be considerably younger.

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[95] Emerson, B. K., General geology: Alaska, vol. 4, p. 26, Harriman Alaska Expedition, 1904.

[96] Moffit, F. H., Gold fields of the Turnagain Arm region: U. S. Geol. Survey Bull. 277, p. 23, 1906.

[97] Grant, U. S., and Higgins, D. F., Preliminary report on the mineral resources of the southern part of Kenai Peninsula: U. S. Geol. Survey Bull. 442, p. 167, 1910.

[98] Martin, G. C., The western part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 52–55, pl. 3, 1915.

The ellipsoidal lava is overlain by the Triassic chert described on pages 47–49, but there is no evidence as to the presence or absence of a stratigraphic break between them. Most of the contacts are not exposed in detail or are faults. The lava is comparatively unaltered and appears to be not very much older than the chert. It may reasonably be assigned either to the Triassic or to the latest Paleozoic. It appears to correspond closely in stratigraphic position and in lithologic character to the Nikolai greenstone of the Chitina Valley.

CHERT

Historical review.—The chert of Kenai Peninsula was first described by Emerson,[99] who briefly noted the occurrence at Halibut Cove of "an interesting section of green and red radiolarian cherts" which he tentatively correlated, on the basis of lithologic similarity, with the Jurassic or Cretaceous radiolarian chert of the Franciscan formation of California. The occurrence of similar chert at Seldovia was noted by Stanton and Martin,[1] who correlated it with the Upper Triassic chert of the west coast of Cook Inlet on the basis of lithologic similarity and assigned it to the Upper Triassic on the basis of this correlation and of its relation to the Lower Jurassic tuff of Seldovia Bay. A more complete discussion of this chert has been given by Moffit,[2] who concluded that it is certainly pre-Jurassic and probably Triassic. The chert was discussed briefly by Grant and Higgins,[3] whose description includes also an account of the underlying ellipsoidal lava, together with a description of the chert associated with the presumably older slate and graywacke. The writer believes that at least part of the last-mentioned chert is not the same as the contorted chert of Seldovia Bay. A rather full discussion of this chert has been given by Martin,[4] who assigned it tentatively to the Upper Triassic and from whose description the following account is taken. The age and correlation of the chert of Kenai Peninsula have also been discussed by Martin.[5]

Stratigraphic description.—Contorted chert occurs in the southwestern part of Kenai Peninsula, along the south shore of Kachemak Bay. The best exposures are on Bear Cove, Halibut Cove, Chinaput Bay, Eldred Passage, Seldovia Bay, and Port Graham.

[99] Emerson, B. K., General geology: Alaska, vol. 4, pp. 26–27, Harriman Alaska Expedition, 1904.

[1] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 393, 1905.

[2] Moffit, F. H., Gold fields of the Turnagain Arm region, Alaska: U. S. Geol. Survey Bull. 277, pp. 16, 17, 19–20, 1906.

[3] Grant, U. S., and Higgins, D. F., Preliminary report on the mineral resources of the southern part of Kenai Peninsula: U. S. Geol. Survey Bull. 442, pp. 167–168, 1910.

[4] Martin, G. C., The western part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 60–63, pl. 3, 1915.

[5] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, p. 699, 1916.

The chert consists of thinly and evenly bedded rocks made up of hard siliceous layers, from half an inch to 2 inches thick, separated by thin films of softer material. The siliceous layers are of fairly uniform appearance except in color. They are of very fine grain, being uniformly of almost glassy texture, and do not contain any recognizable detrital fragments. The material between the hard beds was not definitely determined, but it is probably argillaceous. The color of the chert at most places is green, gray, or black, but a few occurrences of brown or red chert were noted.

The chert is intensely deformed, minute crumpling being general and faulting being common, so that no estimate of the thickness of the formation can be made nor can the top and bottom of a local section be determined with certainty. On the east shore of Seldovia Bay, just above the cannery, the chert apparently rests upon ellipsoidal lava. This is assumed to be the base of the formation, but there may be a fault or an overturn at this point. Within the area of the chert at several places are masses of ellipsoidal lava, which may be either interbedded or structurally included. There is apparent interbedding of thin strata of lava and chert at some localities, but at others there are wider alternate bands of chert and lava that suggest structural repetition. Probably each main mass of chert or lava contains thin interbedded strata of the other rock, and masses of each kind of rock have been included by folding and faulting within the main areas of the other. The only fossils that have been recognized in these rocks are poorly preserved Radiolaria.

Age and correlation.—The contorted chert of Kenai Peninsula has yielded no characteristic fossils, and its age is somewhat doubtful. The local field relations indicate that the chert lies immediately above the ellipsoidal lava and beneath the limestone and tuff, which seem to occur directly beneath the Lower Jurassic beds and to be the youngest Triassic rocks in the local section. This sequence accords well with the relations of similar beds in other regions, provided that the *Halobia* belongs to a species whose range is such that the limestone and tuff can be correlated with the McCarthy formation and with the upper part of the Kamishak chert, and that the chert can be correlated with the chert at the base of the McCarthy and Kamishak formations. But if the *Halobia* is a strictly Karnic species which is restricted to the horizon of the Chitistone limestone and of the lower part of the Hosselkus limestone, the lower part of the limestone and tuff must be correlated with rocks occurring beneath the chert at the base of the McCarthy and Kamishak formations, and the chert can not be considered as occurring beneath the limestone and tuff of Port Graham and be correlated with any of the Triassic cherts known in other Alaskan districts. The writer believes that this *Halobia* is

probably not an exclusively Karnic (lower Hosselkus) species, and that the chert of Kenai Peninsula should be regarded as occurring beneath the limestone and tuff and above the ellipsoidal lava and should be correlated with the chert at the base of the McCarthy formation and with the lower part of the Kamishak chert.

LIMESTONE AND TUFF

Historical review.—The occurrence of Upper Triassic limestone and tuff in the Kenai Peninsula was first noted by Grant and Higgins,[6] who described them briefly as "a series of cherts and black limestones near the base of this [Lower Jurassic] tuff formation." The exposures on Port Graham were subsequently discussed more fully by Martin,[7] who described and mapped these rocks as Upper Triassic limestone and tuff. The southern extension of the belt from Port Graham to Koyuktolik Bay has been mapped and briefly described by Grant.[8] The character, position, and age of the Upper Triassic limestone and tuff of Kenai Peninsula were discussed by Martin.[9]

Stratigraphic description.—The Upper Triassic limestone and tuff of Kenai Peninsula are known only in the vicinity of Port Graham and Koyuktolik Bay. The exposures in these two localities are parts of one continuous belt that extends northward from Koyuktolik Bay, forming the shores of Port Graham for 2½ to 3 miles on each side of the bay, and terminates in the hills between Port Graham and Seldovia Bay.

These rocks consist of limestone with considerable amounts of chert and fine-grained volcanic material, which is mostly tuffaceous. Their thickness is not known, and their stratigraphic relations to the beds that underlie and overlie them have not yet been determined with certainty.

The exposures on the north shore of Port Graham consist of limestone, both cherty and noncherty; rather massive black chert; and volcanic rocks that include tuff, tuffaceous conglomerate, and breccia. The exposures are fairly continuous, but folding and faulting and concealed intervals at critical points make it impossible to measure a complete stratigraphic section or to estimate the total thickness of the beds.

The beds exposed on the south shore of Port Graham seem to correspond to part of those seen on the north shore and include also

[6] Grant, U. S., and Higgins, D. F., Preliminary report on the mineral resources of the southern part of Kenai Peninsula: U. S. Geol. Survey Bull. 442, p. 168, 1910.

[7] Martin, G. C., The western part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 55–59, pl. 3, 1915.

[8] Grant, U. S., The southeastern coast of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 210–211, 227, 1915.

[9] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 698–699, 1916.

beds that were not recognized across the bay, notably those that carry *Pseudomonotis subcircularis* (Gabb). The thickness of the beds exposed on the south shore exceeds 1,000 feet.

Age and correlation.—The fossiliferous Upper Triassic rocks of the Kenai Peninsula, as exposed on Port Graham, are composed of limestone, chert, and tuff at least 1,000 feet thick. *Pseudomonotis subcircularis* (Gabb) occurs near the top of the sequence, and lower down a species of *Halobia* has been found. The former species indicates that at least part of the succession is of Upper Noric age and is to be correlated approximately with the McCarthy formation and with the banded chert and calcareous shale in the upper part of the Kamishak chert. If the *Halobia* is identical with the Alaskan and Californian species usually referred to *Halobia superba* Mojsisovics, it possibly indicates that the lower part of the sequence is of Karnic age and is to be correlated approximately with at least part of the Chitistone limestone of the Chitina Valley and of the Hosselkus limestone of California. The writer would suggest, however, that this *Halobia* and possibly also the one that has been obtained from the west coast of Cook Inlet may belong to the species which Stanton[10] has noted in the lower part of the Brock shale of California or possibly to one of the species[11] that occur in the Lower Noric beds of Oregon. If this is the case, the occurrence of *Halobia* in these beds does not necessarily indicate that they are the equivalent of the Chitistone limestone or that they are older than the supposed Noric strata of California.

Fossils from Upper Triassic limestone of Kenai Peninsula [a]

	6380	6381	6383	6382	6573	7452	7235	7234	10546
Astrocoenia?			×						
Nucula?						×			
Pseudomonotis subcircularis (Gabb)							×	×	×
Halobia cf. H. superba Mojsisovics	×	×		×	×				

[a] Identified by T. W. Stanton.

6380. North side of Port Graham, latitude 59° 21′ 8″, longitude 151° 48′. U. S. Grant, 1909.

6381. South side of Port Graham, latitude 59° 20′ 42″, longitude 151° 49′ 45″. U. S. Grant, 1909.

6383. South side of Port Graham, latitude 59° 20′ 46,″ longitude 151° 49′ 57″. U. S. Grant, 1909.

6382. South side of Port Graham, latitude 59° 21′ 2″, longitude 151° 50′ 24″. U. S. Grant, 1909.

[10] Stanton, T. W., cited by Diller, J. S., U. S. Geol. Survey Geol. Atlas, Redding folio (No. 138), p. 5, 1906.

[11] Smith, J. P., The occurrence of coral reefs in the Triassic of North America: Am. Jour. Sci., 4th ser., vol. 33, p. 95, 1912.

6573. South shore of Port Graham about a quarter of a mile northwest of the wharf (same locality as 6382). G. C. Martin, 1910.

7452. South shore of Port Graham 1 mile below the wharf. G. C. Martin, 1911.

7235. South shore of Port Graham 1½ miles below wharf. G. C. Martin, 1911.

7234. South shore of Port Graham 1⅗ miles below wharf. G. C. Martin, 1911.

10546. North shore of Port Graham near mouth of small stream northeast of cannery. A. C. Gill, 1918.

WEST COAST OF COOK INLET

GENERAL FEATURES

The undoubted Triassic rocks of the west coast of Cook Inlet include two fossiliferous Upper Triassic formations, the Kamishak chert and an older unnamed limestone. The local section also includes greenstone which is older than the fossiliferous Triassic rocks and which probably belongs in the Triassic. Beneath the greenstone is slate which is probably Paleozoic, and above the Triassic rocks are porphyry and tuff that are probably Lower Jurassic. The local sequence is indicated in the following table:

General section of Triassic and associated rocks on west coast of Cook Inlet

Lower Jurassic (?): Porphyry and tuff.
Upper Triassic:
    Kamishak chert.
    Limestone.
Triassic (?): Greenstone.
Paleozoic (?): Slate.

GREENSTONE

The greenstone of the west coast of Cook Inlet, as described by Martin and Katz,[12] includes basic igneous rocks, chiefly of volcanic origin, that are considerably altered at most places. These rocks are probably of general occurrence in association with the Triassic sedimentary formations of the west coast of Cook Inlet, but only those in the vicinity of Iliamna Bay and Ursus Cove have been described in detail.

The greenstone on Cottonwood Bay is in contact with slate, which apparently rests upon the greenstone. The slate is nevertheless believed to be older than the greenstone, as it is more metamorphosed, and the local attitude of the rocks is probably due to a fault or an overturned fold.

[12] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 38–41, 1912.

The contacts of greenstone and granite were seen at many places on Iliamna and Cottonwood Bays, where it is clearly evident that the contacts are intrusive, the granite being the younger. The granite is probably of Lower Jurassic age, so the greenstone is probably Triassic or older.

The sedimentary Upper Triassic rocks of Ursus Cove, which are described on pages 52–54, contain much associated igneous material, some of which closely resembles the greenstone on Cottonwood Bay. This igneous material is most abundant in the lower part of the Ursus Cove section, the relations suggesting that the Upper Triassic sediments grade downward into the greenstone and that the latter possibly belongs within the Triassic.

The greenstone of the west coast of Cook Inlet seems to correspond in position, at least approximately, with the Nikolai greenstone of the Chitina Valley. The local section differs, however, from the section in the Chitina Valley, in that the greenstone of Cook Inlet is apparently overlain by chert beds, whereas the Nikolai greenstone is directly overlain by a massive limestone. This apparent difference may, however, be due to structural disturbances. The greenstone of this district resembles the ellipsoidal lava or greenstone of Seldovia Bay, which is described on pages 45–47, and which, like the greenstone of this district, is underlain by slaty rocks and apparently overlain by contorted chert.

LIMESTONE

Historical review.—The Upper Triassic limestone of the west coast of Cook Inlet forms part of the Upper Triassic rocks of Cook Inlet as described by Stanton and Martin.[13] It includes the Upper Triassic limestone of Iliamna Bay, described by Martin and Katz,[14] and also probably includes at least part of the limestone tentatively referred to the Kamishak chert by the same authors.[15] A brief description and discussion of the age and correlation of this limestone has been published.[16]

Stratigraphic description.—The Upper Triassic limestone of the west coast of Cook Inlet is best exposed on the south shore of Iliamna Bay and probably occurs also on Bruin Bay and Ursus Cove. The limestone on Iliamna Bay occurs in a belt about a mile wide but is so complexly folded that no estimate of its thickness can be

[13] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 396, 1905.

[14] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 41, 43, 44, 45, 46, pl. 2, 1912.

[15] Idem, pp. 47–48.

[16] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 697–698, 1916.

made. The associated rocks consist of amygdaloidal basaltic tuff, probably of Lower Jurassic age, on the west side and granitic intrusives, younger than the limestone, on the east. The structural relations of the tuff to the limestone have not been determined. The granitic rocks are believed to be late Lower Jurassic or Middle Jurassic and are intrusive into the limestone.

The limestone beds on the north shore of Ursus Cove and on the south shore of Bruin Bay are intimately associated with the Kamishak chert and have previously been tentatively assigned[17] to that formation. They are discussed here because of their lithologic character and because their fauna apparently indicates a lower horizon than that of the *Pseudomonotis*-bearing beds in the upper part of the Kamishak chert.

The Upper Triassic rocks of Bruin Bay are described in T. W. Stanton's unpublished field notes as follows:

About a mile within the entrance to the bay a peninsula on the south shore projects half a mile or more into the bay. On the west side of this peninsula there are exposures of a considerable thickness of contorted light-gray and banded chert, cherty limestone, and shale cut by several dikes of greenish igneous rock. In the cherty limestone a few fossils were found that seem to be a small slender *Gryphaea* (3094). This cherty limestone is identical in appearance with that which occurs on the left at the entrance to Seldovia Bay. I think it is Triassic and probably underlies the *Halobia* and *Pseudomonotis* bearing shale. The limestone of 3094 is essentially a part of the banded cherty series and is not separable from it.

Farther around at the northeast angle of the peninsula there are beautiful exposures of folded and faulted cherty and slaty beds banded in black and white so that the structure is very prominent. The most striking feature is a steeply dipping sharp anticline with small faults and many narrow dikes of greenish igneous rock. A short distance south of these contorted beds and in the same continuous exposure the highly inclined black slaty beds yielded a few distorted specimens of a small *Halobia* (3091). These dark and banded Triassic beds in various portions are continuously exposed along the east side of the peninsula to the Indian hut about a quarter of a mile north of the south end of the narrow neck of the peninsula.

It is by no means certain that the limestone beds here described all represent the same horizon. The doubt concerning their identity and position is well shown by the various assignments that have been given to them in the previous descriptions. This doubt probably can not be removed without further field evidence.

The limestone of Iliamna Bay constitutes a formation that is obviously distinct from the Kamishak chert, although the two formations have not been seen in contact. The limestone of Bruin Bay is described above, in Stanton's field notes, as probably underlying the

[17] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 41, 47–48, 1912.

Halobia and *Pseudomonotis* bearing shale, but it is not certain whether the statement that they are "not separable" implied a belief in close stratigraphic relationship or a doubt concerning the feasibility of deciphering the structure. It is doubtful whether the fossils of lot 3091 should be referred to this limestone, for they are described as having been obtained from "black slaty beds." These beds are, however, obviously older than the *Pseudomonotis*-bearing beds that are described on pages 55–56 as the upper member of the Kamishak chert. It is possible that these specimens of *Halobia* were obtained from the typical lower member of the Kamishak chert, which otherwise has possibly not yielded any fossils. The limestone bed on Ursus Cove, from which the fossils of lot 3 were obtained, has previously been regarded as a member of the Kamishak chert and may belong in that formation.

Age and correlation.—The Upper Triassic limestone of the west coast of Cook Inlet has been observed only at places of complex structure and generally in close association with the Kamishak chert. Its exact relations to that formation are somewhat doubtful, but it is believed to underlie the chert. It probably contains a species of *Halobia* which resembles the Alaskan species that is usually compared with *Halobia superba* Mojsisovics, and which may indicate that the limestone corresponds in general position with the Chitistone limestone and is of Karnic age. The following fossils have been collected:

Fossils from Upper Triassic limestone of west coast of Cook Inlet [a]

	2	3	3091	3094
Thecosmylia?	a			
Cora (indeterminate)		a		
Halobia cf. H. superba Mojsisovics			b	
Halobia?	a			
Gryphaea				b
Pecten?				b
Cardium?		a		
Natica? or Naticopsis?		a		

[a] a, Identified by George H. Girty; b, identified by T. W. Stanton.

2. South shore of Iliamna Bay, 1.1 miles S. 75° W. of west end of White Gull Island. G. C. Martin, 1909.

3. North shore of Ursus Cove, at mouth of creek that heads near Cottonwood Bay. G. C. Martin, 1909.

3091. South shore of Bruin Bay, on east side of peninsula 1 mile inside entrance to bay. Black slaty beds. T. W. Stanton, 1904.

3094. South shore of Bruin Bay, on west side of peninsula 1 mile inside entrance to bay. Altered limestone. T. W. Stanton, 1904.

KAMISHAK CHERT

Historical review.—The Kamishak chert constitutes part of the Upper Triassic rocks of the west coast of Cook Inlet as described by Stanton and Martin.[18] This description, although nominally including all the Upper Triassic rocks of Cook Inlet and Alaska Peninsula, was based chiefly upon the occurrence of the Kamishak chert on Ursus Cove and Bruin Bay.

The Kamishak chert was named by Martin and Katz,[19] who described all the observed occurrrences on Cook Inlet and mapped its known distribution. Their description includes some of the limestone beds which are believed by the writer probably to belong in an older formation. (See pp. 52–54.) The reference of these limestone beds to the Kamishak chert was stated,[20] however, to be purely tentative. A description and discussion of the age and correlation of the Kamishak chert[21] has been published.

Stratigraphic description.—The Kamishak chert, which is typically exposed on the west shore of Kamishak Bay, crops out in a more or less continuous belt parallel to the west shore of Cook Inlet from Iliamna Bay to the vicinity of Bruin Bay. The most characteristic exposures of the formation are on the north shore of Ursus Cove, where the section includes 2,000 feet or more of dark chert occurring in fairly massive strata interbedded with thinner layers of shale, sandstone, and limestone. In the lower part of the section there is considerable igneous material, probably partly intrusive, and also some limestone. The limestone has hitherto[22] been tentatively included in this formation but is now assigned to the limestone described on pages 52–54. The following description, which was taken from Stanton's unpublished field notes, applies to the upper part of the section exposed on Ursus Cove:

These beds are much disturbed and in some places highly contorted, consisting of dark-colored, somewhat calcareous shale, banded chert, more dark shale, thin beds of altered limestone, and several hundred feet of greenish and brownish rocks that appear to be intrusive, as along the contact they include masses of the altered shale, chert, etc. There are also small dikes cutting the sediments.

Pseudomonotis was collected in the highest shale exposed near the beach at the entrance to the cove (locality 3086), though there are apparently stratigraphically higher beds exposed near the top of the high hill.

The total thickness of Triassic rocks exposed is probably not less than 1,000 feet, including the intrusive masses. Of the sediments less than half may

[18] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 393–396, 1905.

[19] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 47–50, pl. 2, 1912.

[20] Idem, pp. 47–48.

[21] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 697–698, 1916.

[22] Martin, G. C., and Katz, F. J., op. cit., p. 48.

be described as calcareous shale containing *Pseudomonotis subcircularis* (Gabb) and the rest are light-colored chert. Some of the banded chert and associated igneous rocks and limestone are very suggestive of the older series at Seldovia, though not quite so much altered.

The exposures on Bruin Bay also consist largely of chert, much of which is thin bedded and crumpled. Limestone is present at this locality also, but it possibly belongs to the older formation described on pages 52–54, rather than to the Kamishak chert.

The Kamishak chert consists of banded chert, calcareous shale, and thin limestone in the upper part, grading downward into more massive beds of dark chert. The total thickness is at least 1,000 feet and probably exceeds 2,000 feet. The upper shaly and calcareous part of the formation contains *Pseudomonotis subcircularis* (Gabb), but the lower, more massive chert has thus far yielded no fossils.

Age and correlation.—The fossils represented in the accompanying table were obtained from beds included in the uppermost 1,000 feet of the Kamishak chert as exposed on Ursus Cove. The fossiliferous beds, according to Stanton's description, as given on page 55, consist largely of calcareous shale. The shale is interstratified with chert beds and is underlain, with apparent conformity, by many hundred feet of massive beds of chert that constitute, lithologically, the most characteristic part of the formation. These chert beds have not thus far yielded any fossils, and consequently it is not safe to assume, as the writer has previously done,[23] that the Kamishak chert is characterized by *Pseudomonotis subcircularis* (Gabb). This species is characteristic of the uppermost shaly and calcareous members of the Kamishak chert as that formation was originally defined and shows that these beds are the equivalent of at least part of the McCarthy formation of the Chitina Valley and are probably of Noric age. There is still considerable doubt, however, concerning the exact age and correlation of the lower and more cherty members of the Kamishak chert. There is a strong presumption in favor of correlating them with the chert of the Chitina Valley, which is described on pages 25–26. That chert, however, is likewise of somewhat doubtful age and position, although it apparently belongs near the base of the McCarthy formation and is closely associated with, even though it may not include, beds carrying *Pseudomonotis*. Chert similar to these occurs on the east coast of Cook Inlet (see pp. 47–49) where it has yielded no characteristic fossils and has very doubtful relations to the associated Triassic rocks. Similar chert occurs also on the Alaska Peninsula (see pp. 60–61) where it has yielded no fossils but underlies shale and limestone containing *Pseudomonotis subcircularis* (Gabb).

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[23] Martin, G. C., The western part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 59, 62, 1915.

Each of the localities listed below yielded *Pseudomonotis subcircularis* (Gabb), and 3089 also *Arca.* These fossils were identified by T. W. Stanton.

3086. North shore of Ursus Cove near entrance. T. W. Stanton, 1904.

3088. North shore of Ursus Cove 1¼ miles west of entrance. T. W. Stanton, 1904.

3089. North shore of Ursus Cove 2 miles west of entrance. T. W. Stanton, 1904.

ILIAMNA LAKE

The Triassic rocks of Iliamna Lake and its tributaries include Upper Triassic limestone on the north shore of the lake, limestone of presumably the same age in the mountains east of the lake, and greenstone at several localities on the shores of both Iliamna and Clark Lakes, at least part of which is probably Triassic.

GREENSTONE

The greenstone of Iliamna and Clark Lakes, as described by Martin and Katz,[24] occurs in six areas of more or less altered and partly schistose ferromagnesian rocks, chiefly of volcanic origin but probably including intrusive masses as well as lava and tuff. The evidence concerning the age of these rocks is not strong, and there is considerable uncertainty both in their assignment to the Triassic and in the assumption that they are all of the same age. The reasons for referring them to the Triassic are their general similarity to the supposed Triassic greenstones of other areas, their intrusion by granite rocks that are presumably Middle or Lower Jurassic, and the local absence of the Paleozoic sedimentary formations that are associated with the Paleozoic greenstones elsewhere in Alaska.

LIMESTONE

Historical review.—Fossiliferous Upper Triassic limestone is known in a small area on the north shore of Iliamna Lake, and limestone of probably the same age is present in the hills east of the lake. These occurrences have been described in detail by Martin and Katz,[25] who referred the limestone on the shore of the lake to the Upper Triassic on the basis of statements regarding the character of the fossils, furnished by G. H. Girty and J. P. Smith, which were quoted in the description cited. A brief account of this fauna, with

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[24] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 38–41, 1912.

[25] Idem, pp. 41–47.

a discussion of its age and significance, has been given by Smith.[26] Martin [27] has discussed the age and correlation of this limestone.

Stratigraphic description.—The limestone on the north shore of Iliamna Lake is exposed in the cliffs about 3 miles west of the mouth of Chekok River, or just east of Millet's copper prospects, which are on the western edge of the limestone. The limestone belt is about two-thirds of a mile wide and extends from the lake shore northward over the first ridge and down to the edge of the alluvium-floored valley beyond. The thickness of the limestone has not been measured, but is at least several hundred feet.

The stratigraphic relations of the limestone to the neighboring rocks are obscure and offer little aid in determining its position. The adjacent rocks south of the limestone are tuffs, which have at their base, resting discordantly across the beveled edges of the limestone, a bed of volcanic breccia consisting of angular fragments of limestone in a matrix of volcanic glass. This is regarded as the local base of a series of volcanic beds of Tertiary age. The rocks in contact with the limestone on the east and west sides are basic igneous masses, which have been tentatively correlated on lithologic evidence with other volcanic rocks that are believed to be Lower Jurassic. The relations of the limestone to these supposed Jurassic volcanic rocks have not been determined.

The limestone east of Iliamna Lake, which has yielded no fossils, is in contact with schist of unknown age and with basic igneous masses, in part tuffaceous, now altered to greenstone. This greenstone is certainly older than the Lower or Middle Jurassic granite, which is intrusive into it, and consequently is probably Triassic or older. (See p. 57.) The greenstone appears to be younger than the limestone, although the exact relations have not been positively established. The doubtful point is whether certain rocks that are known to be intrusive into the limestone are an integral part of the main greenstone mass or are younger. Upon this point depends the determination of the age of the limestone. If the greenstone as a whole is younger than the limestone, then the limestone is pre-Triassic. If, however, the basic rocks that cut the limestone are not part of the main greenstone mass, then there is no local proof as to the relative age of the limestone and greenstone, and they can be correlated, as the lithologic evidence seems to warrant, with the similar rocks on Iliamna Lake. This interpretation is accordingly adopted, even though it can not be regarded as positively established.

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[26] Smith, J. P., The occurrence of coral reefs in the Triassic of North America: Am. Jour. Sci., 4th ser., vol. 33, pp. 92–96, 1912.

[27] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 700, 709, 1916.

Age and correlation.—The limestone is of interest because it has yielded a fauna of different type from any found elsewhere in Alaska. The only fossils obtained from this limestone were collected at a single locality on the north shore of Iliamna Lake, 3 miles west of the mouth of Chekok River. This collection was referred to George H. Girty, who determined the fossils to be of Triassic age and described them[28] as follows:

The dominant types of this fauna are the corals, to which I shall refer later. There are in addition an echinoid spine, a large number of fragmentary and ill-preserved pelecypods, a smaller number of gastropods, which are likewise and for the same reason undeterminable, and two species of brachiopods. There are evidently several types among the gastropods and also among the pelecypods. One of the latter is marked by radiating ribs and has the general appearance of *Pecten*, *Lima*, *Pseudomonotis*, etc. There may be two species of this sort. One of the brachiopods, represented by several fragments, is probably a terebratuloid, but its generic affinities are doubtful. The other species is fairly abundant, and it is provisionally referred to *Bittnerula*. This is a rather small plicated shell with ribs also on the fold and sinus. The ventral valve is high and conical, with a high area marked by longitudinal striae, which give the hinge a crenulated appearance. The shell substance is punctate. Fragments of the spiral arms can be seen on the inside. There are also short dental plates which converge and unite with the septum, as in *Cyrtina* and *Bittnerula*. All the Cyrtinas have a simple fold and sinus.

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A comparison of the corals with those described by Frech[29] from the Alpine Trias reveals a striking resemblance between the Alaskan forms and those from the Alps. This is true of the astraeid corals and is especially significant in the case of the spongiomorphine and tubularian forms. In view, therefore, of the fact that this fauna is completely unlike not only any Paleozoic faunas known from Alaska but any known from North America, and that the corals are in the main of types unknown in the Paleozoic and show on the contrary marked affinities with Triassic corals, I am strongly of the opinion that the geologic age of this fauna is Triassic, in spite of the fact that it is unlike any of the known Triassic faunas of Alaska. If this opinion is correct, the occurrence in Alaska of this coral fauna of the Alpine Trias, and especially the development there of the singular group of spongiomorphine corals, is new and important.

This collection was subsequently referred to J. P. Smith, who submitted the following preliminary discussion:[30]

The coral fauna is certainly Upper Triassic, of the lower Noric horizon. The species are closely allied to the Zlambach coral fauna of the Fischerwiese locality in the Alps, which is the best Noric coral fauna known. Some of the species are probably identical with forms I have collected in the Upper Triassic, Noric horizon, of Shasta County, Calif., and are represented by kindred forms in the Blue Mountains of Oregon.

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[28] Girty, G. H., cited by Martin, G. C., and Katz, F. J., op. cit., p. 45.

[29] Frech, Fritz, Die Korallenfauna der Trias: Palaeontographica, vol. 37, pp. 1–116, pls. 1–21, 1890.

[30] Smith, J. P., cited by Martin, G. C., and Katz, F. J., op. cit., pp. 45–46.

These forms will have to be sectioned and studied with the microscope before positive identifications can be made, but the forms capable of more definite determination, and their probable affinities, are listed below:

Preliminary list of fossils from the limestone on Iliamna Lake

Thecosmilia cf. fenestrata Reuss (also in Shasta County, Calif.).
Isastraea cf. profunda Reuss (also in Shasta County, Calif.).
Phyllocoenia cf. incrassata Frech.
Phyllocoenia cf. decussata Reuss.
Stylophyllopsis cf. mojsvari Frech (also in Shasta County).
Astrocoenia cf. waltheri Frech (probably same as in the Noric of Nevada).
Stylophyllopsis cf. zitteli Frech.
Heterastridium sp.? (probably the same as in Oregon).
Spongiomorpha sp.? (probably the same as in Oregon).

A slightly different list of fossils from this locality has been published by Smith,[31] who pointed out that these corals are reef builders and are related to forms that now live only in warm water. Professor Smith correlated this fauna with that of the coral reef zone in the Upper Triassic of Shasta County, Calif., and of Baker County, Oreg. In Shasta County this fauna occurs at the base of the beds that have been correlated with the Noric of Europe.[32] Its position, relative to that of the other Triassic faunas that have been recognized in Alaska is below the beds containing *Pseudomonotis subcircularis*, which belong at the top of the Noric, and above the beds containing *Halobia* cf. *H. superba*, which belong in the Karnic. This fauna may be present, although it has not been recognized, in the upper part of the Chitistone limestone or in the Nizina limestone of the Chitina Valley, or possibly it occurs in beds that have been cut out by an unconformity (see p. 124) at the base of the McCarthy formation. The fauna may also be present on Gravina Island (p. 70), in the Chulitna Valley (p. 45), and on the west coast of Cook Inlet (p. 54).

ALASKA PENINSULA

The Upper Triassic rocks of the Alaska Peninsula, which are known only on Cold and Alinchak bays, include limestone and shale, 700 feet or more in thickness, containing *Pseudomonotis subcircularis* (Gabb), underlain by contorted chert in which no fossils have been obtained. The chert is underlain by basic igneous rocks, and the *Pseudomonotis*-bearing beds are overlain by shale that may be either Triassic or Jurassic.

[31] Smith, J. P., The occurrence of coral reefs in the Triassic of North America: Am. Jour. Sci., 4th ser., vol. 33, pp. 92–96, 1912.
[32] Idem, p. 93.

GREENSTONE

The presence of Triassic (?) greenstone beneath the Upper Triassic sedimentary rocks of the Alaska Peninsula is suggested by the presence on Alinchak Bay[33] of basic igneous rocks that apparently underlie the contorted chert beneath the shale and limestone that contain *Pseudomonotis*.

CHERT

Contorted chert that resembles the Triassic chert of Cook Inlet is exposed on Alinchak Bay[34] and on some of the islands in its mouth. The chert yielded no fossils, but its Upper Triassic age is indicated by the fact that it is apparently underlain by the basic igneous rocks described above and overlain by shale and limestone carrying *Pseudomonotis subcircularis*. (See pp. 61–64.)

SHALE AND LIMESTONE OF COLD AND ALINCHAK BAYS

Historical review.—Triassic rocks crop out in the Alaska Peninsula, as far as is now known, only in an area extending along the south coast from Cold Bay to Alinchak Bay. The Triassic rocks of this area were discovered by Pinart,[35] who collected fossils at Cape Kekurnoi ("Nounakalkhak"), which is at the southeast entrance to Cold Bay. A brief account[36] of the fossils collected by Pinart was given by Fischer, who afterward republished the same description with illustrations.[37] The Triassic fossils from this locality, according to Fischer, consist of a single species, which he described as *Monotis salinaria* Bronn but which has more recently been considered as being *Pseudomonotis subcircularis* (Gabb) or *Pseudomonotis ochotica* (Keyserling). The occurrence of Triassic fossils at this locality has been referred to briefly by Teller,[38] who pointed out that they represented a species of *Pseudomonotis* related to *Pseudomonotis ochotica* (Keyserling). Mojsisovics[39] enumerated this as one of the known occurrences in what he described as the "Arctic-Pacific Trias province." The occurrence of Triassic rocks at this locality was

[33] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, p. 58, 1921.

[34] Idem, p. 58.

[35] Pinart, A. L., Voyage à la côte nord-ouest d'Amérique d'Ounalashka à Kadiak: Soc. géog. (Paris) Bull., 6th ser., vol. 6, pp. 561–580, 1873.

[36] Fischer, P., Sur quelques fossiles de l'Alaska, rapportés par. M. A. Pinart: Compt. Rend., vol. 75, pp. 1784–1786, 1872.

[37] Fischer, P., Sur quelques fossiles de l'Alaska: Voyages à la côte nord-ouest de l'Amérique, pt. 1, pp. 33–36, pl. A, 1875.

[38] Teller, Friedrich, Die Pelecypod-Fauna von Werchojansk in Ostsiberien: Acad. imp. sci. St.-Petersbourg Mém., 7th ser., vol. 33, No. 6, pp. 110, 113, 115, 1886.

[39] Mojsisovics, Edmund von, Arktische Triasfaunen: Acad. imp. sci. St. Petersbourg Mém., 7th ser., vol. 33, No. 6, p. 147, 1886.

mentioned briefly by Dall[40] and by Martin.[41] The Triassic fauna of Cold Bay has been discussed by Frech,[42] who reexamined the fossils collected by Pinart and identified them as including both the typical form of *Pseudomonotis ochotica* (Keyserling) and also *Pseudomonotis ochotica* var. *sparicostata* Teller, the latter being figured. All the accounts mentioned above were based upon the field observations and the collections of Pinart.

The Triassic outcrops on Cold and Alinchak Bays were examined in 1904 by Stanton and Martin, who briefly described them.[43] Their description, however, applies to this occurrence only in a general way, being based chiefly upon the Cook Inlet exposures. This description was repeated by Atwood[44] in his summary of the geology of the Alaska Peninsula. A more complete description, based chiefly on unpublished information obtained by Stanton and Martin in 1904, has recently been published.[45] Additional information, obtained by investigations made in 1921 and 1922, has been given by Capps[46] and by Smith and Baker.[47]

Stratigraphic description.—Triassic rocks form the northeast shore of Cold Bay for at least half a mile inside Cape Kekurnoi and probably extend continuously northeastward along the shore of Shelikof Strait to Alinchak Bay, where they crop out for at least a quarter of a mile along the southwest shore of the bay and on some of the islands in its mouth.

The exposures at Cape Kekurnoi consist of crumpled limestone and calcareous shale cut by dikes and sills of basalt. Within the bay the dip becomes uniformly westward at angles of about 20°, the cliffs exposing a thickness of about 700 feet of limestone and shale similar to those at the cape. Fossils consisting exclusively of *Pseudomonotis subcircularis* (Gabb) are distributed through the upper half of the strata and were collected at several localities (3107) from a quarter to half a mile northwest of the cape. Similar calcareous beds about 100 feet above the highest noted occurrence of *Pseudomonotis* yielded a small collection (3108) of ammonites. A gradual change

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[40] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 865–866, 870, 1896.

[41] Martin, G. C., The petroleum fields of Alaska, with an account of the Bering River coal deposits: U. S. Geol. Survey Bull. 250, p. 51, 1905.

[42] Frech, Fritz, Die zircumpacifische Trias: Léthaea geognostica, Teil 2, Das Mesozoicum; Band 1, Trias, p. 489, pl. 68, figs. 3a, 3b, 1908.

[43] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 393–396, 1905.

[44] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 30–31, 1911.

[45] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 57–58, 1921.

[46] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 91, 92–93, 1923.

[47] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 171–172, 1924.

in the lithologic character of the beds, the rocks becoming less calcareous, begins a short distance northwest of and stratigraphically above this locality. The beginning of this change is regarded as marking the top of the undoubted Triassic rocks. The overlying beds may also belong partly or wholly in the Triassic, but as there are reasons for believing that they may be at least in part Jurassic, and as there is no evidence of a break within them, they will be discussed with the Jurassic rocks on page 183.

The rocks exposed on Alinchak Bay, named in order of age, are basic igneous rocks, contorted chert, and shale and limestone that contain *Pseudomonotis* (3129). The beds that yield *Pseudomonotis* crop out for about 500 feet along the shore. They differ in dip from place to place, but they are nearly everywhere steeply inclined and at some places reach an angle of 45°. The next exposures are a quarter of a mile farther up the shore and consist of Jurassic or possibly Triassic rocks. (See p. 184.)

Some additional information was given by Capps[48] in the following description:

This formation includes a thickness estimated as well over 1,000 feet of hard, dense thin-bedded limestone and limy shale, cut by dikes and sills of basalt. There is evidence that some of the bodies of basalt are lava flows interbedded with the sediments, but this was not proved conclusively. Near Cape Kekurnoi the beds are locally much distorted and folded in several directions, and the included basaltic intrusives are metamorphosed and reticulated with a network of calcite veinlets. Farther northwest, along the shores of Cold Bay, the structure is less intricate, and the beds have a general northeasterly strike and dip 10°-20° NW. Calcite veinlets are abundant in the limestone.

Many layers of the limestone abound in fossil shells which consist almost exclusively of the single form *Pseudomonotis*. * * *

In proceeding northwestward along the shore of Cold Bay, and so getting higher in the stratigraphic section and above the *Pseudomonotis*-bearing beds, the observer notes that the zone of limestone and calcareous shale gradually gives place to less calcareous and more sandy beds, and some distance farther northwest the sandy beds contain fossils of Jurassic age. The Upper Triassic beds are therefore considered to end at the point where the sandy phase begins to appear, but there is apparently perfect conformity between the Triassic and Jurassic beds, the transition having been marked by continuous deposition but a gradual change in the character of the material deposited.

Age and correlation.—The known fauna of the Upper Triassic rocks of Alaska Peninsula consists practically of a single species, *Pseudomonotis subcircularis* (Gabb), which may be the same as *Pseudomonotis ochotica* (Keyserling), of the Triassic rocks of Europe and Asia. This species is characteristic of at least part of the McCarthy formation of the Chitina Valley and has been recognized at many other localities in Alaska. It indicates a horizon

[48] Capps, S. R., op. cit., pp. 92-93.

corresponding to the uppermost Triassic of California and to the Noric of Europe.

This species has been found on the Alaska Peninsula only in limestone and shale, which are underlain, on Alinchak Bay, by contorted chert in which no fossils have thus far been found. The stratigraphic conditions are possibly similar to those on the west coast of Cook Inlet, where this same species is abundant in the uppermost shaly and calcareous members of the beds that have been referred to the Kamishak chert, but not in the more massive chert beds below.

Upper Triassic fossils from Alaska Peninsula [a]

	3107	3108	3129	10821
Stoliczkaria cf. S. granulata (Stoliczka)				×
Pseudomonotis subcircularis (Gabb)	×		×	×
Ammonites (undetermined)		×		

[a] Identified by T. W. Stanton.

3107. Northeast shore of Cold Bay, one-fourth to one-half mile northwest of Cape Kekurnoi. Upper half of 700 feet of limestone and calcareous shale. T. W. Stanton, 1904.

3108. Northeast shore of Cold Bay, about half a mile northwest of Cape Kekurnoi. Calcareous beds about 100 feet above 3107. T. W. Stanton, 1904.

3129. West shore of Alinchak Bay. Shale and limestone overlying contorted chert. Lawrence Martin, 1904.

10821(1–128). North shore of Cold Bay, half a mile northwest of mouth of bay. S. R. Capps, 1921.

KODIAK ISLAND

CHERT AND LAVA

Some chert and lava that are probably Triassic crop out on the southwest coast of Kodiak Island just west of Uyak. They have never been described, except for brief mention in descriptions of the associated schist by Martin [49] and by Maddren.[50]

The supposed Triassic rocks of Kodiak Island include contorted chert and ellipsoidal lava, which are identical in character with the chert and lava of Seldovia, described on pages 45–49. They resemble the rocks at Seldovia in that the chert and lava are intimately but obscurely associated with each other, and also in occurring between a belt of quartzitic schist, crystalline limestone, and chloritic schist and a belt of slate and graywacke.[51] The chert at Uyak has yielded no fossils but can nevertheless be confidently correlated

[49] Martin, G. C., Mineral deposits of Kodiak and the neighboring islands: U. S. Geol. Survey Bull. 542, p. 128, 1913.

[50] Maddren, A. G., The beach placers of the west coast of Kodiak Island: U. S. Geol. Survey Bull. 692, p. 301, 1919.

[51] Martin, G. C., The western part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 44, 60–63, pl. 3, 1915.

with that at Seldovia on the basis of the striking similarity in lithologic character and sequence.

SOUTHEASTERN ALASKA

GENERAL FEATURES

Upper Triassic rocks occur in several small widely distributed areas in southeastern Alaska. They have been recognized at the south end of Gravina Island; possibly on Prince of Wales, Annette, and Revillagigedo Islands; on the Screen Islands; at Hamilton Bay and other neighboring localities on Kupreanof and Kuiu Islands and Keku Islets, near the north end of Keku Strait; at several localities on the southeast shore at Admiralty Island; and near Juneau. At most of these localities the Triassic rocks consist largely of limestone that occurs in close geographic and structural association with Carboniferous and Devonian limestones. As these Paleozoic limestones are widely distributed in southeastern Alaska, as most of their known occurrences are at localities where the structure is complex and the available information is scanty, and as none of the known occurrences of Triassic rocks were recognized in the earlier reconnaissance surveys, it is possible that additional Triassic localities will be found.

The Triassic rocks of southeastern Alaska consist chiefly of limestone having a thickness of apparently only a few hundred feet. A basal conglomerate has been recognized at several localities. The underlying rocks are Permian, except on Gravina Island and at some places on Keku Strait, where they are Devonian, and at Juneau, where they are of unknown age. On Keku Strait the Triassic limestone is underlain locally by ellipsoidal lava, which bears a close resemblance to the lava that underlies the Upper Triassic limestone at many other Alaskan localities. This lava probably overlies Permian limestone. It is possible that much of the greenstone of southeastern Alaska belongs in this position.

The Triassic limestone of southeastern Alaska in general yields faunas containing *Halobia* cf. *H. superba* Mojsisovics, and consequently seems to correspond, at least approximately, in position to the Chitistone limestone, although these faunas contain elements which are not known in the Chitistone fauna and which may indicate either a slightly different horizon or another facies of deposits of the same age. For example, the fossils from Hamilton Bay, near the north end of Keku Strait, include species related to *Spiriferina borealis* Whiteaves and *Trachyceras* (*Dawsonites*) *canadense* Whiteaves, which are elsewhere known only in the Triassic rocks of Liard River, British Columbia, and of Bear Island, between Norway and Spitzbergen, and which are believed to be slightly older

than the *Halobia*-bearing beds. Some of the limestone on Keku Strait also contains ammonites that are suggestive of the Middle Triassic.

The Triassic rocks of the Juneau district contain *Halobia* cf. *H. superba*, but differ from most of the other *Halobia*-bearing beds of Alaska in consisting chiefly of volcanic material.

The Triassic rocks of Gravina Island, which contain only a small proportion of limestone, consisting chiefly of conglomerate and shale, carry a fauna that, although including a species of *Halobia* resembling *Halobia superba* Mojsisovics, is of a somewhat different type from the other recognized Alaskan Triassic faunas. The abundant corals in some of the limestone beds on Gravina Island suggest the Lower Noric coral fauna of Iliamna Lake.

It is only at Hamilton Bay and on Admiralty Island that *Pseudomonotis subcircularis* (Gabb), indicative of the boreal Upper Noric, has been found. At Hamilton Bay, where the strata are overturned, the *Pseudomonotis* zone is separated from the *Halobia* zone by a conglomerate that suggests an unconformity corresponding to the one for which the writer believes there is strong evidence at the base of the *Pseudomonotis* zone in the western part of the Chitina Valley and at Skolai Pass. The beds containing *Pseudomonotis* near Hamilton Bay, according to Buddington, are intercalated with ellipsoidal lava.

Other volcanic rocks at localities on Keku Strait near Hamilton Bay are interbedded with limestone and calcareous sandstone that contain a Triassic fauna of a very different type from any that has been found elsewhere in America. The beds that contain this fauna have not been found in contact with either the *Halobia*-bearing or the *Pseudomonotis*-bearing rocks. They might be correlated either with the volcanic rocks that lie beneath the *Halobia*-bearing beds or with the lava which Buddington believes is interstratified with the *Pseudomonotis*-bearing beds. The evidence from the fossils is not conclusive but is suggestive of a horizon near the top of the Triassic.

On Admiralty Island there is a contorted chert that is somewhat similar to the Upper Triassic chert of Cook Inlet. It apparently overlies the Triassic limestone, but has yielded no fossils and may not be Triassic.

The top of the Triassic beds of southeastern Alaska has not been recognized except on Gravina Island, where the Triassic rocks are overlain by volcanic beds that are believed to be Lower or Middle Jurassic, and at Juneau, where they are overlain by volcanic beds that may also be Jurassic, but it is probably marked by a great unconformity, for the next younger sedimentary rocks known at most places are Upper Jurassic or Lower Cretaceous.

CONGLOMERATE, LIMESTONE, SANDSTONE, AND SLATE OF GRAVINA ISLAND

Historical review.—The rocks of Gravina Island that are now known to be of Upper Triassic age were first described by Brooks,[52] who named them the "Gravina series" and at first referred them to the Cretaceous, on the basis of a correlation with the somewhat similar rocks of the Queen Charlotte Islands. His later conclusion [53] was that "on reviewing the evidence its identity with the Vancouver series (Triassic) seems equally probable."

These rocks were mapped by F. E. and C. W. Wright [54] as "undifferentiated Paleozoic" but were not described except in the statement [55] that fossils, which were provisionally referred to the early Carboniferous but which "may represent a Triassic horizon," were found in beds of calcareous schist. These authors also quoted a statement prepared by G. H. Girty giving a list and discussion of these fossils. Brief mention of the fossiliferous beds 3 miles north of Dall Head has been made also by C. W. Wright,[56] who mapped these rocks as undifferentiated Paleozoic.

These rocks were first referred definitely to the Triassic by Smith, who collected fossils of undoubted Upper Triassic age and who described the fossiliferous and associated beds in considerable detail.[57] His account of these rocks includes detailed descriptions of the exposures and lists of fossils determined by Stanton. The rocks on the east coast of Gravina Island, described by Smith as Triassic, include the conglomerate, graywacke, and slate that were subsequently referred to the Upper Jurassic or Lower Cretaceous.

A description of the Triassic rocks of Gravina Island by Martin [58] includes brief mention of the lithology, fauna, and stratigraphic relations of the beds, based in part on his own field observations and in part on the description by Smith.

Some Triassic crinoids from the west coast of Gravina Island, collected by the writer and Theodore Chapin, have been described and figured by F. A. Bather.[59]

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[52] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska: U. S. Geol. Survey Prof. Paper 1, pp. 25, 40, 45, 52, 69, pl. 2, 1902.

[53] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 226, 1906.

[54] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pls. 1, 2, 1908.

[55] Idem, pp. 52–53.

[56] Wright, C. W., Geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 87, p. 18, pl. 1, 1915.

[57] Smith, P. S., Notes on the geology of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 95, pp. 100–104, 1915.

[58] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 700–701, tables opp. pp. 687, 716, 1916.

[59] Bather, F. A., The Triassic crinoids from New Zealand collected by Dr. C. T. Trechmann: Geol. Soc. London Quart. Jour., vol. 73, pp. 247–256, 1917.

The description of the Triassic rocks of Gravina Island by Chapin[60] includes discussions of the distribution and character, structure, stratigraphic relations, origin, and age and correlation of the rocks of Gravina Island that are here referred to the Triassic and also of some more metamorphosed unfossiliferous rocks on Revillagigedo Island which Chapin correlated with them on the basis of lithologic similarity and structural relations. The account contains lists of fossils identified by T. W. Stanton and J. B. Reeside.

Stratigraphic description.—The Mesozoic rocks of Gravina Island include the Upper Triassic and Jurassic or Cretaceous beds represented in the following section:

Section of Mesozoic rocks on Gravina Island

	Feet
Lower Cretaceous (?): Conglomerate, graywacke, and black slate with *Belemnites*	800±
Upper Jurassic (?): Slate and limestone interbedded with tuff and containing *Aucella*	1,200± (Upper Jurassic and Lower or Middle Jurassic)
Lower or Middle Jurassic (?): Breccia, tuff, and lava	
Upper Triassic:	
Black slate with thin beds of limestone and sandstone and some conglomerate	1,600± (Upper Triassic, all beds)
Massive limestone	
Black slate interbedded with some graywacke and limestone	
Massive conglomerate with limestone lenses	
Unconformity (Devonian limestone beneath).	

The Upper Triassic rocks of Gravina Island are underlain unconformably by Devonian limestone. They are overlain, with apparent conformity according to Chapin,[61] but with probable unconformity according to Smith,[62] by the breccias, lava, and tuff which the writer refers tentatively to the Lower or Middle Jurassic. The breccia, lava, and tuff were referred by Smith[63] to the Jurassic or Cretaceous because of their lithologic resemblance to the supposed Upper Jurassic or Lower Cretaceous augite melaphyre in the region north of Juneau. They were referred by Chapin[64] to the Upper Triassic and Jurassic because they grade upward with apparent conformity into tuff interbedded with slate and limestone which have yielded specimens of *Aucella* that are "probably Upper Jurassic or possibly Lower Cretaceous" and because he regarded them as

[60] Chapin, Theodore, The structure and stratigraphy of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 120, pp. 89–95, 1918.

[61] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo Islands, Alaska: U. S. Geol. Survey Prof. Paper 120, pp. 95, 96, 1918.

[62] Smith, P. S., Notes on the geology of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 95, pp. 104–105, 1915.

[63] Idem, pp. 104–105.

[64] Chapin, Theodore, op. cit., pp. 95–97.

equivalent to the black slate and schistone tuff at Ketchikan, which he correlated with the Upper Triassic slate and greenstone at Juneau.

The following description of the Upper Triassic rocks of Gravina Island is chiefly quoted from the description by Chapin.[65]

The Upper Triassic rocks on Gravina Island comprise a conformable series of conglomerates, limestones, sandstones, and slates about 1,600 feet thick. They are most typically exposed on the southwest coast of the island, where they occupy a narrow belt that extends from a small cove opposite Dall Bay northwestward for about 7 miles.

The Upper Triassic rocks fall naturally into three main divisions—one composed essentially of conglomerate, one essentially of limestone, and one of interbedded black slate, sandstone, conglomerate, and limestone. These three conformable terranes are shown by fossils to be probably Upper Triassic. Overlying the Upper Triassic sediments, with apparent conformity, are volcanic agglomerates, breccias, and lavas which are overlain by tuffs, slates, and limestones containing fossils of Upper Jurassic or Lower Cretaceous age.

The exposed basal member of the series on Gravina Island is a coarse conglomerate that extends along the southwest coast of the island from Conglomerate Point northwestward to Open Bay and occupies three narrow strips whose continuity is broken by Fivemile Cove, Thompson Cove, and Threemile Cove. The conglomerate is a heavily bedded, massive rock. The boulders are essentially of angular coarse-grained granite resembling the granite of Annette Island, and the matrix is quartz-feldspar sand presumably derived from the same source as the boulders. Intercalated with the coarse conglomerate are thin beds of sandstone, which are composed of the same material as the matrix of the conglomerate, and gradational beds of grits. Thin beds of fossiliferous limestone and black slate with pronounced cleavage occur sparingly. The conglomerate and intercalated sandstone beds are strongly indurated and break with prominent fractures across the boulders.

On a small cove south of Threemile Cove[66] the conglomerate is finer grained toward the top and passes upward into grits, sandstone, and slate which are overlain by a large block of fossiliferous massive limestone. There has been some movement along this contact, so that the relations are confused, but the limestone is apparently above the conglomerate and sandstone. On Thompson Cove the conformable relations of the limestones to the conglomerate, sandstone, and slate are more evident, although here also there has been some faulting.

In the upper part of the conglomerate the beds are thinner and the material is much finer grained and contains more sandstone, slate, and thin beds of limestone, which are conformably overlain by the massive limestone.

The limestone varies in appearance from place to place. On Thompson Cove and Open Bay it is a soft gray fossiliferous rock, corals being especially abundant. On Threemile Cove it is more closely folded, is considerably silicified, and weathers out brick red. The limestone here is less fossiliferous, and the fossils are poorly preserved. The greater amount of deformation of the limestones on Threemile Cove is probably the result of contact metamorphism induced by the intrusive rocks of Dall Head.

The massive limestone is conformably overlain by a great thickness of black slate with intercalated beds of conglomerate, sandstone, and limestone.

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[65] Chapin, Theodore, op. cit., p. 90.

[66] Threemile Cove has appeared in the literature as "cove 3 miles north of Dall Head."

These beds crop out along the coast of Gravina Island for a distance of about 3 miles north of the limestone area and extend to the high hills of Dall Ridge north of Dall Head. Similar rocks are exposed on Bostwick Inlet and Seal Cove and extend northwestward in a belt from 2 to 3 miles wide to Vallenar Bay and North Vallenar Point.

The dominant rocks of this series are black clay slates having a pronounced cleavage. Intercalated with the slate are thin beds of quartz sandstone, quartzite, and conglomerate sandstone. The limestone beds are not numerous but are usually fossiliferous. The interbedded limestone layers are about 20 to 30 feet in thickness but appear to be lenticular.

The black slate and associated sediments are closely folded, especially on Threemile Cove, where the beds are thrown into sharp contorted folds. The beds on Vallenar Bay are much more regular and show none of the close folding.

Age and correlation.—The Upper Triassic rocks of Gravina Island have yielded the fossils listed in the following table. The complex structure and the discontinuity of exposures make it impossible to determine the precise sequence of all the fossil localities, but it is believed that the localities are arranged in the table approximately in stratigraphic sequence, the oldest at the left. The fossils of lot 9899 were obtained from narrow bands of limestone interbedded with the basal conglomerate. The massive limestone and the beds between it and the basal conglomerate are believed to have yielded lots 9535, 8832, 8831, 8830, 9531, and 9536. The thin-bedded limestone and intercalated slate overlying the massive limestone probably yielded lots 8835, 8834, 8829, 9900, 10097, 112, 9537, 9538, 9534, 121, and 8836. The slate and limestone in the upper part of the sequence are believed to have yielded lots 9532, 9533, 8704, 8705, and 124.

The fossils are not well preserved and most of the collections, except those containing *Halobia* cf. *H. superba*, are not characteristic even of the Triassic. The fossils suggest, however, that two distinct faunas may be present. The limestone members contain abundant corals with a variety of other fossils, including crinoids, brachiopods, and mollusks, among which are no species, except the corals, that have been recognized in any of the other Alaskan Triassic faunas. The corals apparently belong to the Lower Noric fauna that is found in the Triassic limestone of Iliamna Lake. (See pp. 59–60.) Concerning the fossils in lot 9900 Reeside[67] said: "These forms are apparently of the Upper Triassic coral fauna referred by J. P. Smith to the Noric." Another collection which contains fossils that are different from those in most of the Triassic rocks of Alaska, although it includes some characteristic Triassic genera, is lot 8836, concerning which Stanton[68] said: "This assemblage suggests the

[67] Reeside, J. B., cited by Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo islands: U. S. Geol. Survey Prof. Paper 120, p. 93, 1918.

[68] Stanton, T. W., cited by Chapin, Theodore, idem, p. 94.

fauna of the lower part of the Modin formation in California, which was tentatively assigned to the Jurassic."

The slate that apparently overlies the coral-bearing limestone contains *Halobia* cf. *H. superba* Mojsisovics, which suggests an approximate correlation with the Chitistone limestone and indicates a lower horizon than the coral fauna. It is possible that the Triassic rocks of Gravina Island are inverted or that some of the species have a different range in Alaska from that which has been recognized in other regions.

Upper Triassic fossils from Gravina Island [a]

	9899	9535	8832	8831	8830	9531	9536	8835	8834	8829	9900	10097	(EMK)	(112)	9537	9538	9534	(121)	8836	9532	9533	8704	8705	(124)
Isastraea cf. I. profunda Reuss											b													
Thamnastraea cf. T. rectilamellosa Winkler											b													
Spongiomorpha?											b													
Undetermined corals			a		a	a	a	a	a	a		a	a		a		a	a						
Hydrozoan											b													
Isocrinus gravinae Bather																		c						
Isocrinus			a																					
Cidaris?	b																				a			
Echinoid spines						a												a						a
Bryozoa?							a								a									
Rhynchonella?				a																				
Terebratula																			a					
Spiriferina?								a						a				a	a					
Undetermined brachiopods													a											
Solemya?																		a						
Nucula																			a					
Macrodon												a												
Cassianella									a										a					
Halobia cf. H. superba Mojsisovics																				a	a	a	a	
Halobia		a																						
Halobia?													a	a										
Ostrea?					a	a											a	a						
Gryphaea?		a				a										a								
Myophoria															a				a					
Myophoria?								a	a															
Myophoria or Trigonia																			a					
Pecten						a	a												a					
Pecten?		a																						
Plicatula?																			a					
Astarte?																			a					
Undetermined pelecypods													a											
Murchisonia?									a															
Turbo?															a									
Pseudomelania?					a			a																
Purpurina??							a								a									
Natica								a	a															
Natica?						a					b													
Turritella?						a		a									a	a						
Cerithium?											b													
Undetermined gastropods							a					a	a				a							
Cosmonautilus?				a																				
Trachyceras? (small fragment)								a																
Arcestes?																			a					
Arcestes?? (fragment)					a																			
Undetermined ammonite		a																						

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside; c, identified by F. A. Bather.

9899 (16 ACh 136). Threemile Cove, north shore, just west of low gap leading northward to Thompson Cove. Limestone lenses in massive conglomerate. Theodore Chapin, 1916.

9535 (15 ACh 123). Thompson Cove, north shore. Black slate interbedded with graywacke and limestone and overlying the massive conglomerate exposed at the mouth of the cove. Theodore Chapin, 1915.

8832 (4). Near south foreland on south arm of Threemile Cove. Near contact with conglomerate. G. C. Martin, 1914.

8831 (3). South arm of Threemile Cove, on shore east of wooded island. Large limestone nodule in conglomerate. G. C. Martin, 1914.

8830 (2). South arm of Threemile Cove. Massive limestone outcrop near anchorage behind wooded island, apparently at least 100 or 200 feet above 8834. G. C. Martin, 1914.

9531 (15 ACh 111). Inlet 2½ miles north of Dall Head. Massive gray limestone beds near the head of the inlet. At the mouth of the inlet is massive conglomerate, which passes up into sandstone and slate. The limestone overlies the slate apparently conformably, although the slate is crumpled, and the relations are not evident. Theodore Chapin, 1915.

9536 (15 ACh 129). Open Bay, 5 miles north of Dall Head. Thin bedded limestone apparently overlying the massive conglomerate exposed along the west coast of Gravina Island. The limestone is blue and weathers brown. Interbedded with it is black slate. Theodore Chapin, 1915.

8835 (7). Reef west of cabin on north arm of Threemile Cove. Thin-bedded limestone interstratified with shale, about 20 or 30 feet below 8834. G. C. Martin, 1914.

8834 (6). North arm of Threemile Cove. Massive limestone in reef west of cabin, 20 or 30 feet above 8835. G. C. Martin, 1914.

8829 (1). North arm of Threemile Cove. Float on outcrop of shale and thin limestone beds of localities 8834 and 8835. G. C. Martin, 1914.

9900 (16 ACh 137). Threemile Cove, east shore, 200 yards north of low pass leading to east coast of island. Lenses of limestone interbedded with black slates. Theodore Chapin, 1916.

10097. Threemile Cove. Lenticular limestone interbedded with slate. Edwin Kirk, 1917.

(EMK). "Cove 3 miles north of Dall Head." Exact locality not known. E. M. Kindle (?), 1906.

—— (15 ACh 112). Threemile Cove, 300 yards north of 15 ACh 111. Thin beds of limestone interbedded with conglomeratic sandstone and slate. These beds are believed to overlie the massive gray limestone (15 ACh 111). Their relations, however, are concealed. Theodore Chapin, 1915.

9537 (15 ACh 130). Open Bay, 5 miles north of Dall Head. From same locality but from beds overlying those of 9536 conformably. Theodore Chapin, 1915.

9538 (15 ACh 132). Open Bay, 5 miles north of Dall Head, immediately north of 15 ACh 130. Overlying the beds at 15 ACh 130 a conglomerate occurs which grades into an impure gritty limestone with quartz and limestone pebbles and many fossils at 15 ACh 132. These conglomeratic beds pass upward into black slate. Theodore Chapin, 1915.

9534 (15 ACh 122). Northeast shore of Thompson Cove. Small fault block adjoining that of 15 ACh 121. Theodore Chapin, 1915.

—— (15 ACh 121). Northeast shore of Thompson Cove. Small fault block of limestone. Theodore Chapin, 1915.

8836 (8). West shore of Bostwick Inlet near entrance. Angular nodules in a brecciated (?) nodular limestone. G. C. Martin, 1914.

9532 (15 ACh 113). Threemile Cove, 300 yards southeast of north end of cove and about 700 yards north of 15 ACh 112. Black slate and limestone, apparently overlying the rocks of 15 ACh 111 and 112 and the red-weathering gritty limestone. Theodore Chapin, 1915.

9533 (15 ACh 115). Thompson Cove. *Halobia* slate similar to that at 15 ACh 113. At this locality it occupies a fault block on the south arm of the cove and lies between conglomerate and nodular limestone. Theodore Chapin, 1915.

8704. Threemile Cove, "north of the center of the small bay on the northern limb of the appressed pitching syncline." Probably about 100 feet above 8834. P. S. Smith, 1913.

8705. Open Bay. P. S. Smith, 1913.

—— (15 ACh 124). Dall Ridge, one-fourth mile northeast of Thompson Cove. Thin beds of limestone apparently interbedded with sandstone and slate. Theodore Chapin, 1915.

TRIASSIC (?) ROCKS OF PRINCE OF WALES, ANNETTE, AND REVILLAGIGEDO ISLANDS

The presence of Triassic rocks is suspected but not definitely established at various localities in the Ketchikan district, notably on Prince of Wales, Annette, and Revillagigedo Islands. The following information concerning these localities is taken from a manuscript report by Chapin:[69]

Conglomerate, sandstone, and slate on Annette Island are probably the equivalent of the Gravina Island sedimentary formations and may include both Triassic and Upper Jurassic or Cretaceous.

Small areas of conglomerate, sandstone, and black slate that occur on Hotspur Island are believed to be Upper Triassic. They unconformably overlie the Middle Devonian limestone and greenstone and occupy the flanks of a very closely compressed anticline with the Middle Devonian beds exposed along the crest of the fold. The only fossils which these sediments yielded are some *Favosites* in the limestone boulders included in the conglomerate. On lithologic similarity, these sediments are regarded as Upper Triassic and correlated with similar rocks on Gravina Island.

A small area of conglomerate, sandstone, and black slate that occurs on Hunter Bay resembles the Triassic rocks of Gravina Island. These sediments unconformably overlie the Middle Devonian greenstone but are very closely folded with Paleozoic rocks, from which they were not differentiated in the mapping. The only fossils found in these beds were boulders of Devonian limestone, found in the conglomerate. Other rocks regarded as possibly Triassic are some shales infolded with Middle Devonian limestone on Clover Bay on Prince of Wales Island. These beds contain fossils determined as "possibly Triassic or later."

Clover Bay is a small indentation 4 or 5 miles north of the mouth of Cholmondeley Sound on Prince of Wales Island. A small mass of fossiliferous limestone and other sediments too small to map occurs near the head of the bay inclosed within a mass of intrusive quartz diorite. These rocks comprise beds of conglomerate, graywacke, argillite, and limestone, which strike N. 60° W. and stand at a steep angle. The following sequence of rocks is exposed:

[69] Chapin, Theodore, The Ketchikan district: U. S. Geol. Survey Bull. — (in preparation).

Apparent section on Clover Bay, Prince of Wales Island

	Feet
Quartz diorite.	
Limestone with Middle Devonian fossils	15
Conglomerate graywacke with fossils, probably Triassic? (lot 152)	12
Concealed	25
Argillite	20
Limestone with Middle Devonian fossils	10
Argillite	10
Graywacke	30
Concealed	43
Graywacke with fossils, probably Triassic (lot 9539)	10
Limestone with Middle Devonian fossils	22
Graywacke	17
Argillites with dikes of quartz diorite	43
Quartz diorite.	

In the field this section was regarded as consisting of interbedded limestone and graywacke, but upon the fossil evidence it appears that the limestone is Middle Devonian and that the graywacke is probably Mesozoic and therefore younger. * * * The beds are closely folded and overturned. The Middle Devonian limestone comes to the surface along the crests of the anticlines and is overlain by the younger sediments which occupy the synclines.

On the east side of the mouth of Klakas Inlet extending from Klinkwan Village to Tah Bay is an unmapped area of conglomerate and black slate with a little sandstone, which unconformably overlie the Middle Devonian greenstone and tuff. The base of the formation is conglomerate carrying limestone boulders that contain Middle Devonian fossils, and overlying the conglomerate are black slate and sandstone. The age of these rocks is not clear. They may possibly be correlated with sediments that occur in the upper part of the Middle Devonian, or they may be younger rocks. If Middle Devonian they mark an unconformity which was not recognized elsewhere. In general appearance they resemble the Triassic rocks of Gravina Island more than they do any known Middle Devonian rocks, and they may be Triassic. On the map these rocks were not differentiated from the Devonian sediments which they overlie.

Greenstone which Chapin described as "schistose green tuff" and referred to the "Upper Triassic or Jurassic" is present on Revillagigedo Island near Ketchikan and on the opposite shores of Tongass Narrows. This schistose green tuff was called "greenstone schist" by Brooks [70] and the "green schist near Ketchikan" by Smith [71] and was regarded by both as Paleozoic. According to Chapin's interpretation of the structure of Gravina and Revillagigedo islands the tuff stratigraphically overlies the massive igneous rocks that carry Jurassic fossils and occupies a position near the top of the formation. Its schistose nature he believed to be due to contact metamorphism induced by the intrusive masses of Revillagigedo Island, as indi-

[70] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, p. 48, 1902.

[71] Smith, P. S., Notes on the geology of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 95, p. 100, 1915.

cated by the increase of schistosity toward the igneous rocks on the northeast. Chapin [72] described these rocks as follows:

The black slates and green bedded tuffs are best developed along the north shore of Tongass Narrows from Ketchikan to Mountain Point. The black slates are in places considerably metamorphosed and schistose and might more correctly be called phyllites. They are closely interbedded with and grade into fissile green tuffs, both of which are interbedded with more massive tuffs. The green tuffs are also schistose and in places completely recrystallized. The greater part of the town of Ketchikan stands on rocks of this character, and excavations for street building show both the blocky and fissile types. The most schistose types are completely recrystallized and consist of secondary quartz, feldspar, calcite, epidote, and chloritic material. The massive types consist essentially of secondary epidote, hornblende, chlorite, sericite, and calcite, with pyroxene and plagioclase feldspar crystals almost entirely replaced by secondary minerals.

The greenstone of Tongass Narrows was referred to the Mesozoic by Chapin on the basis of an assumption concerning its structural relations to the Mesozoic rocks of the west and south coasts of Gravina Island and on the basis of a correlation with the Mesozoic greenstones near Juneau. The evidence for its assignment to the Mesozoic, in the writer's opinion, is weak, and it may with equal confidence be referred to the Carboniferous or Devonian.

The supposed Mesozoic rocks of Annette and Hotspur islands have yielded no conclusive evidence as to their age, but there is no special reason to doubt that they are Mesozoic.

The supposed Triassic rocks of Prince of Wales Island have yielded a few fossils concerning which T. W. Stanton has submitted the following statement:

9539 (15 ACh 154). Head of Clover Bay, Prince of Wales Island. Small block of limestone inclosed in granite:

Rhynchonella? sp.
Pelecypod fragments.
Possibly Triassic or later. Fossils not diagnostic.

9540 (15 ACh 199). Klakas Inlet, west coast of Prince of Wales Island, opposite Max Cove:

No determinable fossils.

9541 (15 ACh 202). Max Cove, Klakas Inlet, west coast of Prince of Wales Island:

Several obscure undetermined corals.
Triassic or older.

9542 (15 ACh 206). East shore of Keete Inlet, west coast of Prince of Wales Island, 1½ miles from head of inlet. Limestone interbedded with green slate and andesite:

Fragments and obscure imprints of pelecypods, mostly Aviculidae.
Triassic or older.

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[72] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo islands, Alaska: U. S. Geol. Survey Prof. Paper 120, pp. 95–96, 1918.

TRIASSIC (?) LIMESTONE OF SCREEN ISLANDS

Historical review.—The occurrence of Triassic limestone on the Screen Islands, which are situated in Clarence Strait near the west coast of Etolin Island, was first suggested by F. E. and C. W. Wright,[73] who enumerated this as one of the localities of Triassic "gray argillaceous limestone, fossiliferous calcareous sandstone, conglomerate." A brief description of the rocks at this locality has been given by A. F. Buddington.[74]

Stratigraphic description.—Thick-bedded limestone and conglomerate, in a highly disturbed condition, form the Screen Islands, off the west coast of Etolin Island, in Clarence Strait. These beds comprise two limestone formations separated by a thick and massive conglomerate; the upper limestone and the conglomerate are probably Triassic, and the lower limestone may be Carboniferous. On the northernmost island, according to Buddington, beds about 900 feet thick are exposed, comprising limestone with intercalated beds of coarse conglomerate and conglomeratic and sandy limestone about 200 feet thick. The cobbles and pebbles in the conglomerate are predominantly chert and limestone, with some rhyolite porphyry and greenstone.

The section exposed on the Screen Islands, according to the unpublished field notes of E. M. Kindle, is as follows:

Section of Triassic (?) and Carboniferous (?) rocks on Screen Islands

	Feet
1. Conglomerate bands in much wider bands of blue-gray limestone	50
2. Dark-gray hard limestone. Fossils (lot 22G) from lower 35 feet	400
3. Covered	50
4. Black, rather soft shale	50
5. Dark-gray to blackish limestone; few small pebbles (partly covered)	110
6. Conglomerate, containing large limestone pebbles full of Carboniferous fossils (lot 22C) and other pebbles, interbedded with bands of hard blue limestone 1 to 3 feet thick	140
7. Dark-gray to buff limestone, with large *Spirifer* at base	50
8. Black argillaceous limestone, with fossils (lot 22A)	160

Age and correlation.—The lower limestone, which is exposed on the more northerly islands, yielded the Carboniferous (?) fossils collected by the writer in 1914, of which G. H. Girty says:

[73] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 34, 1908.

[74] Buddington, A. F., Mineral deposits of the Wrangell district, southeastern Alaska: U. S. Geol. Survey Bull. 739, p. 53, 1922.

Intrinsically they might be Carboniferous, but they are so unlike the usual run of Alaskan Carboniferous faunas that I am disposed to think that they may be Triassic. I have provisionally identified the following species:

Lot 12. Next to the northernmost of Screen Islands:
- Pseudomonotis sp.
- Aviculopecten? aff. A. fasciculatus.
- Pleurotomaria? sp.

Kindle also obtained from the lower limestone (bed 8 of the section on p. 76) some fossils concerning which Girty submitted the following statement:

Lot 22A. Screen Islands:
- Tegulifera? sp.
- Pseudomonotis? sp.

These [lots 22A and 22G] differ from any other Alaskan Carboniferous fauna known to me. Intrinsically, while they contain types that are unusual and interesting, they seem to be without anything which is diagnostic. I am at present unable to say either that they are Carboniferous or that they are not, and as there seems to be a certain amount of extrinsic evidence for supposing that they do represent that period, I have accepted them, though only very provisionally.

The conglomerate that forms bed 6 of the section on page 76 contains fossiliferous pebbles from which several collections have been made. The fossils of lot 22C, which were collected by Kindle, have been determined by Girty as upper Carboniferous. As these fossils were obtained, according to Kindle's notes, from "large limestone pebbles" in a conglomerate, they prove the age of the rock from which the pebbles were derived, rather than the age of the conglomerate that now contains them. The fossils in the pebbles are not only upper Carboniferous but represent the youngest Carboniferous fauna known in Alaska. They consequently indicate that the conglomerate in which they are now contained is probably post-Carboniferous. Fossils obtained by Buddington from limestone cobbles in conglomerate on the largest island were identified as of Carboniferous age, from which Buddington concluded that the conglomerate probably overlies the lower limestone unconformably.

The upper limestone, which crops out only on the southernmost island, yielded the Triassic (?) fossils represented in the following table:

Fossils from upper limestone on Screen Islands [a]

	8839	8838	(22G)	11075	11076	(2)	(3)	(4)
Corals							b	
Crinoidal fragments			b					b
Archaeocidaris? sp			b					b
Burrows		a						
Dielasma sp			b					
Terebratula?	a							
Cyrtia sp			b					
Spiriferina?				a				
Aviculopecten sp			b					
Pecten?		a						
Pelecypods					a			
Pleurotomaria sp			b					
Murchisonia? sp			b					
Tuberculopleura? sp			b					
Several undetermined forms			b					
Ammonite						b		

[a] a, Identified by T. W. Stanton; b, identified by G. H. Girty.

8839. Near south end of the southernmost of Screen Islands, 100 or 200 feet below 8838. G. C. Martin, 1914.

8838. South end of the southernmost of Screen Islands. Nearly the highest beds exposed on this island. G. C. Martin, 1914.

(22G). Screen Islands. Bed 2 in section on p. 76. E. M. Kindle, 1905.

11075. South tip of southernmost of Screen Islands. A. F. Buddington, 1921.

11076. Southwest side of longest of Screen Islands. A. F. Buddington, 1921.

(2). Screen Islands. G. H. Girty, 1918.

(3). Near north end of northernmost of Screen Islands. G. H. Girty, 1918.

(4). Screen Islands. G. H. Girty, 1918.

TRIASSIC ROCKS OF KEKU STRAIT AND VICINITY

Historical review.—The Upper Triassic rocks at Hamilton Bay, which were the first Triassic rocks to be recognized in southeastern Alaska, became known through the discovery by E. M. Kindle, in 1905, of a loose fragment of fossiliferous limestone at the head of the bay. Kindle did not describe his discovery, but the occurrence was mentioned briefly by F. E. and C. W. Wright [75] in a general account of the geology of southeastern Alaska. The locality was revisited in 1907 by Atwood,[76] who found the Triassic rocks in place and who has given a brief account of the occurrence, to which Stanton contributed lists of the fossils and a discussion of their age and significance. Additional collections from the north shore of Hamilton Bay were made in 1914 by Martin,[77] who has briefly discussed the rocks and their faunas. More detailed investigations of these rocks were made in 1922 and 1923 by A. F. Buddington, who has contributed, from his field notes and manuscript report, much of the information presented below.

[75] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 34, 57, 1908.

[76] Atwood, W. W., Some Triassic fossils from southeastern Alaska: Jour. Geology, vol. 20, pp. 653–655, 1912.

[77] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 700–701, 706, 1916.

Stratigraphic description.—The Triassic rocks exposed on Hamilton Bay and elsewhere on the shores and islands at the north end of Keku Strait comprise both sedimentary and volcanic beds. The sedimentary rocks include conglomeratic limestone or calcareous conglomerate, calcareous sandstone or sandy limestone, black shale, and limestone. Most of the limestones are fine-grained gray rocks with some black slaty layers. The conglomerate and sandstone are restricted to the basal sedimentary beds. The volcanic rocks include green andesitic lava, breccia, and tuff, with local intercalated sedimentary beds. The lava predominantly shows a pillow structure and is in part amygdaloidal. Some of the breccia has a limestone matrix.

No complete section of the Triassic rocks on Keku Strait has been found, because the continuity of the exposures is interrupted in so many places by structural disturbances or by areas of water. The evidence on the stratigraphic relations of the rocks, obtained by the several observers at different localities, is conflicting.

The Triassic rocks observed by Atwood are on the north shore and adjacent islands of Hamilton Bay about halfway between Kake and the head of the bay. They include a bed of limestone conglomerate, which Atwood [78] described as

> a peculiar formation in that there are huge angular blocks of limestone in it associated with boulders ranging from 1 to 3 feet in diameter. The conglomerate formation is at least 100 feet thick and may represent an important structural division line in the Mesozoic section.

According to Atwood's field notes, this conglomerate is underlain by "dark-red brittle, much jointed argillite" containing *Pseudomonotis subcircularis* (Gabb) (lot 4819) and is overlain by the beds containing *Halobia superba* Mojsisovics? (lot 4823). It has been suggested by Stanton [79] that, as the limestone conglomerate occurs between the horizons of lots 4819 and 4823, both of which are definitely determined to be Triassic, "Nos. 4821 and 4822 may have come from concretions rather than boulders." It should be noted that the beds at this locality are apparently not in their normal sequence, the *Pseudomonotis* indicating a higher horizon than the *Halobia*. It is possible, therefore, that the beds are locally overturned. In that case the conglomerate may mark an unconformity corresponding to the one that possibly occurs in the Chitina Valley (see p. 124) between the beds containing *Halobia* and those containing *Pseudomonotis*. It is also possible that the "limestone conglomerate" that Atwood described as containing "angular blocks of limestone" is in reality a coarse fault breccia, the fault having produced the local inversion of the strata.

[78] Atwood, W. W., op. cit., p. 654.
[79] Stanton, T. W., cited by Atwood, W. W., idem, pp. 654–655.

The writer, in studying the section on the north shore of Hamilton Bay east of the localities visited by Atwood, found that ellipsoidal lava is exposed from the head of the bay to the islands that fringe the lower part of the northern shore, except for an interval of about half a mile about 2 miles below the head of the bay. The lava dips southeast and thus apparently overlies the Permian limestone exposed on the creek entering the head of the bay, although the contact was not seen. It is apparently overlain by Upper Triassic dark cherty limestone, which is exposed on the north shore from a point 2 miles below the head of the bay to the mouth of the creek half a mile farther down the shore. This limestone was observed practically in contact with the underlying ellipsoidal lava. As there is a considerable discordance in strike and dip between the limestone and the lava, the contact is either an unconformity or a fault. The thickness of the limestone exposed along this part of the shore does not exceed a few hundred feet and may be less than 100 feet. *Halobia* was obtained near the base of the limestone (lot 8843) and *Pseudomonotis* from somewhat higher beds (lot 8844). The writer believes that the exposures at this locality are not complete, the presence of Upper Triassic beds older than the *Halobia*-bearing beds being indicated by fossils found in float collected along the shore (lots 8842 and 8845).[80]

The Triassic rocks of the localities at the north end of Keku Strait are regarded by A. F. Buddington as probably including three formations—a formation, exposed chiefly on Kuiu Island, that lies unconformably on Permian and Devonian rocks and is made up chiefly of basaltic and andesitic lavas, breccia, and tuff interbedded with some sedimentary rocks including a basal conglomerate and some limestone containing fossils that are believed to be Upper Triassic; a formation that lies, in most places, unconformably on Permian and Devonian rocks, is composed wholly of sedimentary rocks, mostly conglomerate, limestone, and sandstone, and contains fossils that are chiefly characteristic Upper Triassic forms such as *Halobia* cf. *H. superba* and its customarily associated ammonites; and a formation that is believed to lie unconformably on the sedimentary formation just described and is composed chiefly of lava and tuff with some intercalated slate, quartzite, and limestone containing *Pseudomonotis*.

The following notes on the undoubted Upper Triassic sedimentary rocks seen at various localities at the north end of Keku Strait were submitted by Mr. Buddington:

On the north side of the Cornwallis Peninsula about a mile southeast of Point Cornwallis the contact between the Upper Triassic and the Permian beds is exposed. The Upper Triassic limestone is very gently folded and extends

[80] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 700, 706, 1916.

along the shore, with local interruptions, for 2½ miles. At the northern contact the Triassic beds are gently folded and rest on Permian limestone with white chert layers. The basal beds of the Triassic limestone contain pebbles of white chert. At the southern contact the Triassic limestone lies unconformably on volcanic rocks that are probably Permian. The limestones are locally fossiliferous (11931 and 11932).

About 4 miles from the head of Hamilton Bay is a small elongate island north of which the following section was measured:

Section of Upper Triassic rocks behind island 4 miles below head of Hamilton Bay

	Feet
Volcanic rocks.	
Quartzite and limestone with *Pseudomonotis* (lot 11437)	25±
Bluish-gray and black limestone with fossils (lots 11243, 11241, 11242, 11240)	100
Calcareous sandstone and limestone	125
Calcareous sandstone and sandy limestone	50
Coarse conglomerate with calcareous matrix	100
Unconformity (Permian limestone beneath).	

Several hundred feet of limestone, black calcareous shale, and chert is exposed on the west side of the narrow neck joining the two portions of the large island several miles south of Kake. Conglomerate, sandstone, and black slate about 125 feet thick apparently overlie these beds. The conglomerate is overlain by volcanic rocks with intercalated fossiliferous slate beds containing *Pseudomonotis* (11246).

At the northwest end of the large island south of Kake the basal Upper Triassic conglomerate rests directly on Devonian chert and tuff. The pebbles in the conglomerate are mostly chert, with some green tuff like that in the underlying Devonian beds. The conglomerate contains fossiliferous limestone nodules (11237). The Upper Triassic rocks here consists of about 100 feet of conglomerate, thin-bedded limestone, calcareous sandstone, and slate, overlain by limestone of unknown thickness, above which is a most extraordinary appearing volcanic agglomerate.

Mr. Buddington has submitted the following statement concerning the supposed uppermost volcanic formation:

The *Pseudomonotis*-bearing volcanic rocks of Hamilton Bay lie, probably unconformably, upon the calcareous sedimentary Upper Triassic rocks.

Along the southwest limb and at the southeast nose of the Kake anticline a conglomerate bed, in part of volcanic origin and 150 to 200 feet or more thick, lies at the base of the volcanic rocks. This bed was not found elsewhere. On the west side of the narrow neck in the long island south of Kake several hundred feet of the limestone, black calcareous shale, and somewhat crumpled chert, which belong in the older beds described above, are overlain by about 125 feet of conglomerate, sandstone, and black slate. These beds are believed to represent the base of the volcanic series. The conglomerate has a greenish hue on the fresh surface but weathers with a reddish glazed appearance. It is composed of fragments of chert, in part carrying Permian fossils, andesite, and black slate. Many of the fragments are angular, and those of sedimentary rock are from Paleozoic formations, but the volcanic fragments are similar to the Upper Triassic lava. The beds are overlain by andesitic lava with associated thin beds of black slate, calcareous quartzite, and limestone. Fossils were obtained (11246) from layers between pillow lava.

Northwest of the large island south of Kake are two small islands formed in part of volcanic breccia and in part of beds that may be either breccia or conglomerate. The rocks are much sintered and consequently weather with a glazed surface. There are about 200 feet of these beds consisting of very coarse conglomerate at the base and medium-grained conglomerate above. The fragments comprise black slate, andesite, andesite porphyry, chert, green tuff, calcareous quartzite, and limestone. Some of the chert is fossilliferous and is presumably upper Carboniferous, whereas the green tuff is doubtless Upper Devonian. Many of the fragments are sharply angular; others are rounded. One 2-foot boulder of andesite porphyry had a 2-inch chill zone surrounding it. In thin section fragments of andesite show similar chill zones completely surrounding them. Fragments of unmistakable perlite were seen; vesicular and amygdaloidal volcanic rocks are abundant, and feldspar fragments very common. These phenomena suggest that volcanic material and perhaps fragments of underlying sedimentary beds were showered by volcanic explosions into waters where normal conglomerate was accumulating. Hence the beds are correlated with the volcanic series.

The volcanic rocks are exposed along the southwest limb of the Kake anticline, as on the southwest side of the long island south of Kake. They here comprise pillow lava from 5 to 20 feet thick, massive and polygonal jointed flows from 10 to 30 feet thick, and sedimentary beds from 1 inch to 10 feet thick. The sedimentary beds consist of black slate, quartzite, and limestone. On the extreme northwest headland of this island the sedimentary beds are broken to fragments and included in a glassy andesitic matrix. Each individual fragment is usually inclosed in a ball of glass, so that on weathering the appearance is that of a very coarse agglomerate. The diameter of most of the fragments is about 9 inches, but blocks as large as 18 by 300 feet were seen. The upper beds are finer, the fragments ranging from the size of a hickory not to that of an apple. The breccia beds stand about vertical and are about 150 feet across the strike. At the south end the contact between the breccia and the sedimentary beds is at an angle to the strike of the sediments.

The volcanic rocks are again exposed within the Cape Bendel syncline, along the north side of Hamilton Bay, where they consist of amygdular and pillow lava, in part variolitic, with intercalated sedimentary beds. The interstices between the pillows are filled with limestone and the pillows show a radial jointing and an outer vesicular crust. A peculiar feature of some of the more massive flows is a pseudo-breccia structure in which the fragments have not been displaced more than an inch at the maximum but still maintain their relative positions and are separated by a limestone filling. The intercalated sedimentary beds consist of black calcareous slate, gray quartzite, and thin limestone bands. Many of the layers are highly fossiliferous (11245).

The following notes on the supposed Upper Triassic volcanic rocks of Kuiu Island and on some beds that are their possible equivalents were submitted by Mr. Buddington:

Near the point west of Hound Island, where the shore turns southward, the Permian beds are overlain by sandstone with conglomeratic layers followed by interbedded limestone and green andesitic tuff with a few layers of conglomerate. About three-fifths of a mile south of the point the limestone is fossiliferous (11406). These beds are overlain by basaltic and andesitic lava, breccia, and tuff with interbedded limestone containing a few andesite pebbles.

The entire peninsula between Six and a Quarter Fathom Cove and the cove south of it is composed of coarse agglomerate and pillow lava. The agglomer-

ate predominates in the western half of the peninsula, and the flows with interbedded agglomerate in the eastern half. Here also the pillow lava with interstitial limestone is seen to grade upward into breccia with a limestone matrix. At a point on the east side of the peninsula, west of Pup Island, there is a conspicuous pillow lava with layers of limestone 12 inches or less thick molded to the surfaces of the ellipsoids. The limestone is baked to a pinkish-brown hornstone at the contact with the lava. Some of the limestone pockets are extraordinarily rich in well-preserved fossils (11407 and 11962). Hound Island and several islets northwest of it consist of green andesitic breccia with a limestone matrix, which is interbedded with a little dense buff-weathering or agglomeratic limestone.

Turnabout Island, off the northwest end of Kupreanof Island, consists of andesite and andesite porphyry lava and breccia with intercalated tuff and a 50-foot bed of gray sandstone. The flows are in part amygdular and in part have pillow structure. The sandstone lies on the east side of a bight on the south side of the island and contains thin layers of calcareous sandstone and conglomerate, some of which are richly fossiliferous (11405). Traces of carbonized plant stems are also common.

In the northern part of the cove just south of Cape Bendel the basal Upper Triassic beds consist of interbedded conglomerate and lava having a thickness of 100 feet or more. Green Devonian tuff lies west of the Triassic rocks. The cobbles of the conglomerate consist of limestone, chert, and green Devonian tuff. Some beds are composed almost wholly of fragments of red shale. On the east side of the syncline the base of the formation consists of about 100 feet of conglomerate interbedded with lava and sandy fossiliferous limestone (11933). The beds here overlie the Permian. Overlying these basal beds comes a series of volcanic rocks which comprise predominantly green andesitic lava, chiefly with pillow structure but in part amygdaloidal. The lava, including the conglomerate at the base, was estimated to be approximately 1,400 feet thick. About 1¼ miles northeast of Cape Bendel, on the east headland of a cove due south of Pinta Rocks, a zone of sedimentary beds about 225 feet thick is intercalated within the andesitic lava. These beds consist of about 50 feet of conglomerate which grades upward into sandstone and is overlain by isoclinally folded thin-bedded limestone. Many of the limestone layers are highly fossiliferous (11934). These beds are overlain and underlain by pillow lava.

Age and correlation.—The apparent stratigraphic succession and the character of the Triassic faunas on Keku Strait are somewhat different from anything that has been found elsewhere in Alaska. The fossils from the limestone and associated sedimentary rocks that are regarded by Buddington as forming the basal portion of the Triassic rocks of this locality and the fossils from sedimentary beds that he regards as intercalated in the overlying volcanic formation are listed in the following table. Most of these collections include well-known Upper Triassic species that are characteristic of the Triassic rocks of other Alaskan localities, such as *Pseudomonotis subcircularis* (Gabb) and *Halobia* cf. *H. superba* Mojsisovics, as well as some of the ammonites that are customarily associated with the *Halobia.*

Upper Triassic fossils from north end of Keku Strait [a]

	11931	11932	11933	4822	4821	8842	8845	8846	8841	11934	11237	11238	11239	11240	11241	11242	11243	8843	4823	9543	10196	10197	11408	11436	11245	11246	11437	4820	4819	8844	(16B)
Plant stems?	X																														
Cup corals	X																														
Corals?							X																								
Rhynchonella		X		X	X					X																					
Terebratula	X						X	X		X																					
Terebratula?		X													X																
Spiriferina borealis Whiteaves?							X																								
Spiriferina										X																					
Spiriferina?					X					X																					
Brachiopods			X																												
Pseudomonotis subcircularis (Gabb)																									X	X		X	X	X	X
Pseudomonotis subcircularis (Gabb)?																								X			X				
Pseudomonotis?										X																					
Halobia cf. H. superba Mojsisovics										X	X	X	X	X			X	X	X		X	X									
Halobia															X					X			X	X	X	X					
Ostrea?	X																														
Pecten				X					X	X																					
Lima?																					X										
Modiolus										X																					
Pleuromya?				X																											
Astarte?									X					X			X														
Undetermined pelecypods	X	X	X	X			X																								
Natica							X	X																							
Gastropods	X																														
Mojsvaroceras?														X																	
Tropites																X															
Paratropites											X	X			X		X														
Discotropites sandlingensis (Hauer)?											X		X	X		X	X														
Discotropites												X																			
Juvavites?														X																	
Sagenites?															X																
Ceratites	X																														
Ceratites?																			X												
Clionites?											X																				
Trachyceras cf. T. canadense Whiteaves						X																									
Trachyceras (Protrachyceras)								X																							
Trachyceras?				X					X																						
Placites?												X		X																	
Polycyclus?													X		X																
Arcestes											X						X														
Undetermined ammonite				X			X																								
Atractites								X						X										X							

[a] Identified by T. W. Stanton.

11931 (No. 910). Kuiu Island, about 3 miles southeast of Point Cornwallis, on Keku Strait side. Gently folded limestones. A. F. Buddington, 1923.

11932 (No. 961). Kuiu Island, opposite round island about 4 miles southeast of Point Cornwallis. Limestone apparently overlying felsite breccia and tuff. A. F. Buddington, 1923.

11933 (No. 980). Kupreanof Island, about 2 miles northeast of Cape Bendel. Brown sandy limestone between the white Permian limestone and the conglomerate. May be either basal portion of Upper Triassic or upper part of Permian. A. F. Buddington, 1923.

4822 (7). North side of Hamilton Bay near south end of large island southeast of Kake. Boulder in limestone conglomerate. W. W. Atwood, 1907.

4821 (6). North side of Hamilton Bay near south end of large island southeast of Kake. Another boulder in the limestone conglomerate. W. W. Atwood, 1907.

8842 (16). North shore of Hamilton Bay, about 2 miles below head of bay. Float. G. C. Martin, 1914.

8845 (19). North shore of Hamilton Bay, about 3 miles below head of bay. Float. G. C. Martin, 1914.

8846 (20). North shore of Hamilton Bay, about 3 miles below head of bay. Float. G. C. Martin, 1914.

8841 (15). Hamilton Bay, about three-fourths of a mile up the northernmost creek entering the head of the bay. Gray limestone that appears to underlie the white Carboniferous limestone at the falls near the mouth of the creek. R. M. Overbeck, 1914.

11934 (No. 979). 1¼ miles northeast of Cape Bendel, Kupreanof Island, on east headland of cove due south of Pinta Rocks. Near top of limestone. A. F. Buddington, 1923.

11237 (39). About 2 miles south of Kake, on northwest point of large island. Limestone nodules in calcareous conglomerate beds intercalated in limestone at top of conglomerate series (basal conglomerates). A. F. Buddington, 1923.

11238 (92). Extreme southeast tip of large island south of Kake. Limestone overlying basal (?) conglomerate series. A. F. Buddington, 1923.

11239 (91). Limestone overlying that of 92; many interlayers of slate. A. F. Buddington, 1923.

11240 (62). 7 miles southeast of Kake, on Kupreanof Island. Limestone overlying conglomerate and sandstone. A. F. Buddington, 1923.

11241 (67). Limestone beds a trifle above those of 11240 and about 350 feet above base of conglomerate series. The underlying buff-weathering Carboniferous (?) limestone with chert layers is exposed beneath the conglomerate. A. F. Buddington, 1923.

11242 (66). Limestone beds at about same horizon as 11241, on islet just south of 11241. On nose of anticline pitching southeast. A. F. Buddington, 1923.

11243 (68). Same locality as 11240, about 275 feet above base of conglomerate series. Limestone. A. F. Buddington, 1923.

8843 (17). North shore of Hamilton Bay, 2 miles below head of bay. Near base of cherty limestone that overlies ellipsoidal lava. G. C. Martin, 1914.

4823 (8). North side of Hamilton Bay, near south end of large island southeast of Kake. Beds that seem to overlie the limestone conglomerate that yielded lots 4821 and 4822. W. W. Atwood, 1907.

9543. Islet in Frederick Sound, one-fourth mile southwest of Kake. Mrs. Theodore Chapin, 1915.

10196. South end of northernmost large island of Keku Islets. G. H. Girty, 1918.

10197. Near middle of north shore of small island southeast of northernmost large island of Keku group. G. H. Girty, 1918.

11408 (211 Bu). Northeast end of large island southeast of northernmost large island of Keku group. Black calcareous shale adjacent to limestone with white chert beds. Shale probably same formation as 215 and 205. A. F. Buddington, 1922.

11436 (205 Bu). Southwest side of northernmost large Keku Islet. Same formation (?) as 215 but more sheared. A. F. Buddington, 1922.

11245 (56 Bu). North shore of Hamilton Bay, about 2 miles below head of bay. From thin-bedded slate, quartzite, and limestone intercalated with pillow lava. These beds overlie the limestone beds of 66 and 67. A. F. Buddington, 1922.

11246 (68). West shore of large island southeast of Kake. From similar beds to 56 intercalated in pillow lava overlying limestone of 91. A. F. Buddington, 1922.

11437 (65 Bu). Kupreanof Island, southwest of Kake. From interbedded quartzite and limestone overlying the limestone of 67. A. F. Buddington, 1922.

4820 (2). North side of Hamilton Bay near south end of large island southeast of Kake. Beds that seem to underlie the limestone conglomerate that yielded lots 4821 and 4822. W. W. Atwood, 1907.

4819 (1). North side of Hamilton Bay near south end of large island southeast of Kake. Same series of beds that yielded lot 4820, apparently a few feet lower. W. W. Atwood, 1907.

8844 (18). North shore of Hamilton Bay, 2 miles below head of bay. About 40 or 50 feet above lot 8843. G. C. Martin, 1914.

(16 B). Near head of Hamilton Bay. Float. E. M. Kindle, 1905.

The fossils of lots 11245 to 16B are indicative of the Upper Noric *Pseudomonotis*-bearing beds that constitute the upper most known Triassic rocks of other Alaskan regions. The fossils of lots 11934 to 11436, all of which contain *Halobia*, most of which contain *Halobia* cf. *H. superba*, and some of which contain several of the ammonites that are generally associated with *Halobia* cf. *H. superba*, are indicative of the Middle or Upper Karnic *Halobia*-bearing beds that generally underlie the *Pseudomonotis*-bearing beds of other regions.

The fossils of lots 11931 to 8841, in which both *Pseudomonotis* and *Halobia* are absent, call for special consideration. The fossils of lot 11931 include an ammonite which Stanton has identified as *Ceratites*. This ammonite, if correctly identified, is suggestive of the Middle Triassic. Lots 11932 and 11933 contain only a few fossils that are not of any special significance. Lots 4822 to 8841, from boulders in the Upper Triassic conglomerate, from float of unknown origin, and from beds that apparently underlie the Permian rocks at an isolated locality on the creek that enters the head of Hamilton Bay, differ from the faunas at the other localities not only in the absence of *Pseudomonotis*, of *Halobia*, and of the ammonites that are generally associated with *Halobia*, but in the presence of *Trachyceras* and of abundant brachiopods. The float material of lots 8842, 8845, and 8846 was noted in the field as having come "from beds that

were not recognized in the observed outcrops." The fossils at localities 8842 and 8845 include species related to *Spiriferina borealis* Whiteaves and *Trachyceras* (*Dawsonites*) *canadense* Whiteaves, which have not been found elsewhere in Alaska or at any American localities except in the Triassic rocks of Liard River, in the eastern foothills of the Rocky Mountains of British Columbia.

The Triassic rocks of Liard River, according to McConnell,[81] "consist of dark shales, usually rather coarsely laminated, and passing into calcareous shales interstratified with sandstones and shaly and massive limestones." The fossils, which have been described by Whiteaves,[82] include 11 species, among which are *Spiriferina borealis* Whiteaves and *Dawsonites canadense* Whiteaves, which have been doubtfully identified from Hamilton Bay. Mojsisovics[83] has pointed out that some of these fossils are indicative of Karnic age. Three of the Liard River species (*Dawsonites canadense*, *Nathorstites mcconnelli*, and *Nathorstites lenticularis*), one of which occurs at Hamilton Bay, have been found, according to Böhm,[84] in the Upper Triassic rocks of Bear Island, between Norway and Spitzbergen. The Triassic rocks of Bear Island are generally regarded as of Karnic (possibly Lower Karnic) age, and an assignment of the beds on Liard River to the same position has been made by Frech[85] on the basis of the presence of the above-mentioned species, which are common to the two regions.

The Hamilton Bay fauna may also be tentatively correlated with that from Bear Island and referred to the Karnic. This fauna possibly represents a boreal facies of the Karnic which has not been recognized farther south in North America.

The fauna of the limestone and calcareous sandstone interbedded with the lava and tuff of Kuiu Island is very different from any of the previously known Triassic faunas of America. Concerning this fauna, which is represented in the table given below, T. W. Stanton has furnished the following statement:

Although this small collection [lot 11407] contains an unusually large number of species of fairly well preserved fossils which are apparently of Mesozoic types, there seems to be nothing in it strictly comparable with any known Mesozoic fauna in Alaska or indeed in America. Several of the species do not show important characters that are necessary for positive generic as-

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[81] McConnell, R. G., Report on an exploration in the Yukon and Mackenzie basins, Northwest Territory: Canada Geol. Survey Ann. Rept., new ser., vol. 4, pp. 19D, 49D, 1890.

[82] Whiteaves, J. F., On some fossils from the Triassic rocks of British Columbia: Contr. Canadian Paleontology, vol. 1, pt. 2, No. 3, pp. 127–149, pls. 17, 18, 1889.

[83] Mojsisovics, Edmund von, Beiträge zur Kenntniss der obertriadischen Cephalopoden-Faunen des Himalaya: K. Akad. Wiss. Wien Denkschr., Band 63, p. 697, 1896.

[84] Böhm, Johannes, Ueber die obertriadische Fauna der Bäreninsel: K. svenska Vetenskaps-Akad. Handlingar, Band 37, No. 3, pp. 56–58, 61–64, 73–76, 1903.

[85] Frech, Fritz, Die zircumpacifische Trias: Lethaea geognostica, Teil 2, Das Mesozoicum, Band 1, Trias, pp. 488–491, 508, 1908.

signment, and this fact weakens the determination of the age of the fauna. It is reasonably certain, however, that this fauna belongs to the Triassic and probably to the Upper Triassic, as determined by comparison with European Triassic faunas.

Fossils from Upper Triassic (?) limestone and calcareous sandstone associated with lava and tuff on Keku Strait [a]

	11407	11962	11406	11405
Wood fragments			×	
Sponge?			×	
Pentacrinus	×	×		
Cidaris? and other echinoids (spines)	×	×		
Heteropora		×		
Rhynchonella	×	×		
Rhynchonella (Austriella?)	×	×		
Terebratula	×	×	×	
Terebratula?				×
Spiriferina	×	×	×	
Spiriferina?			×	
Macrodon	×	×		
Macrodon?	×	×		
Pinna?		×		
Gervillia	×			
Gervillia?		×		
Pteria		×		
Pteria?	×	×	×	
Ostrea? (small plicate form)			×	
Gryphaea?				×
Myophoria?	×	×		
Pecten (with strong concentric ribs)	×	×		
Pecten (slender radiating ribs and coarse internal lirae)	×			
Pecten				×
Pecten (Propeamusium)		×		
Lima (with fine sculpture)		×		
Lima (coarse-ribbed form)		×		
Lima (rotund form with fine sculpture)	×			
Lima (small form with strong ribs)	×			
Lima? (another ribbed form)		×		
Placunopsis?	×	×		
Mytilus	×			
Astarte?	×			
Cardita?	×	×		
Gonodon?	×	×		
Protocardia?	×	×		
Undetermined pelecypods			×	×
Scurria?	×	×		
Pleurotomaria	×			
Pleutotomaria?		×		
Worthenia? (several species)	×	×		
Euomphalus	×	×		
Euomphalus?	×			
Coelocentrus?	×	×		
Trochus	×	×		
Trochus? (a sinistral specimen)		×		
Neritopsis		×		
Pseudomelania?		×		
Anoptychia?	×			
Eustylus?	×			
Promathilda?	×			
Platyceras?		×		
Spirocyclina?	×	×		
Undetermined gastropods		×	×	
Arapadites?	×	×		
Ammonite		×		

[a] Identified by T. W. Stanton.

11407 (256 Bu). Kuiu Island, 3 miles a little north of west of Point Camden, on west side of 9¾-fathom cove about halfway between 9¾ mark and north point. Conspicuous pillow lava involved, with thick layers of limestone molded to the pillows. One pocket of limestone extraordinarily rich in well-preserved fossils. The limestone for several inches adjacent to pillow is baked to a pinkish-brown hornstone. Fossils are all from this pocket. A. F. Buddington, 1922.

11962 (256 Bu). Same locality as 11407, but on different pocket. Kuiu Island, 3 miles a little north of west of Point Camden, on west side of 9¾-fathom cove. A. F. Buddington, 1923.

11406 (244 Bu). Kuiu Island, west side of Keku Strait, 7 miles northwest of Pup Island, just north of first creek shown on chart south of point where shore line changes from east-west to north-south. Interbedded argillaceous limestone and andesitic tuff, with rare thin conglomerate beds and intercalated sandstone. Many layers of the limestone are richly fossiliferous. Traces of leaf impressions poorly preserved are present in same layers with shells; and carbonized plant stems are common in the limestone and abundant in the sandstone. A. F. Buddington, 1922.

11405 (145 Bu). Turnabout Island, Frederick Sound. East side of the bight, on the south side of the island, where the house stands. Basalt and basalt porphyry flows and breccia with intercalated tuff and a 50-foot bed of gray sandstone. The sandstone contains intercalated layers of calcareous sandstone and conglomerate 1 inch to several inches thick, some of which are richly fossiliferous. Traces of carbonized plant stems also noted in the sandstone. A. F. Buddington, 1922.

An assignment of the volcanic beds containing these fossils to a position beneath *Halobia*-bearing limestone would accord with the occurrence of volcanic rocks immediately beneath the *Halobia*-bearing limestone in other parts of Alaska, notably in the Chitina Valley (pp. 6–10) and on Cook Inlet (pp. 45–49). There are difficulties, however, in the assignment of the rocks to this position. The *Halobia*-bearing beds at near-by localities rest unconformably upon Devonian and Permian rocks. If the beds that contain the fauna in question belong under the *Halobia*-bearing beds they are separated from the *Halobia*-bearing beds by an unconformity and consequently are considerably older. The fossils themselves, according to an oral statement by T. W. Stanton, are suggestive of a horizon above that of *Halobia* or even above that of *Pseudomonotis* rather than of a horizon below that of *Halobia* cf. *H. superba*. The writer believes, therefore, that the volcanic rocks containing this fauna are to be correlated with the lava and tuff which Buddington regards as interbedded with the rocks that contain *Pseudomonotis*, or may even be assigned to some horizon even higher in the Noric or in the Rhaetic. The volcanic beds that overlie the Triassic rocks of Gravina Island, which the writer has referred tentatively to the Lower or Middle Jurassic, may possibly belong at the same horizon.

TRIASSIC LIMESTONE OF ADMIRALTY ISLAND

Historical review.—Upper Triassic rocks are exposed at several localities near the south end of Admiralty Island. The rocks at these localities were considered Carboniferous by C. W. Wright,[86] who obtained upper Carboniferous fossils near by, and have never

[86] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pp. 142–143, pl. 33, 1906.

been described as Triassic, except for a brief mention[87] of the rocks near Herring Bay. Edwin Kirk has contributed additional information concerning some of these localities but has not published any description of them.

Stratigraphic description.—The Triassic rocks of Admiralty Island consist chiefly of limestone. The section at Herring Bay includes 273 feet of limestone and shale, which are faulted upon Lower Cretaceous shale and are overlain by unfossiliferous chert, shale, and conglomerate that may also be Triassic. The Triassic fossils from Pybus Bay were obtained from limestone, possibly only 40 or 50 feet thick, which rests upon Permian (?) conglomerate and is overlain by Lower Cretaceous shale. The Triassic fossils near Carroll Island were obtained from argillite and sandstone. No information is available concerning the character of the Triassic rocks on Mole Harbor and between Gambier Bay and Point Pybus.

The following section was measured by the writer on the south side near the extremity of the cape between Chapin and Herring Bays. Most of the outcrops are low reefs, covered by the highest tides and consisting of steeply dipping rocks, which do not furnish conclusive evidence as to which are the lower and which the upper beds. The sequence indicated in the following section is based on an assumption that the strata are not overturned and that the contact with the apparently underlying Lower Cretaceous shale is a bedding fault rather than an unconformity.

Section of Upper Triassic rocks on point at north entrance to Herring Bay, Admiralty Island

	Feet
1. Green shale and chert	20
2. Conglomerate	38
3. Thin-bedded limestone	18
4. Fossiliferous thin-bedded limestone (lot 8849)	2
5. Thin-bedded contorted limestone	40
6. Limestone and gray shale	40
7. Massive limestone	47
8. Limestone and gray shale	24
9. Fossiliferous limestone (lot 8848)	3
10. Limestone and gray shale	28
11. Fossiliferous limestone (lot 8847)	1
12. Gray shale and limestone	70
Fault (Lower Cretaceous shales beneath).	

North of these exposures, or just around the cape toward Chapin Bay, are outcrops of black contorted chert and shale. These beds are apparently higher than those of the section just described and were regarded in the field as probably Triassic. It is possible, how-

[87] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, p. 701, inset opp. p. 687, 1916.

ever, that the entire section is overturned. In that case the conglomerate that constitutes bed No. 2 of the preceding section should probably be regarded as the basal member of the Triassic rocks, and the shale and chert are probably the source of the upper Carboniferous fossils that were collected at or near this locality by Wright.[88]

The following section was measured by E. M. Kindle at or near the same locality as the section given above. The writer believes that bed No. 2 of Kindle's section is probably the same as bed No. 2 of the preceding section.

Section on point off Chapin Bay

	Feet
1. Grayish-white massive chert conglomerate	250
2. Coarse conglomerate with large and small pebbles of green and gray chert. Thin fossiliferous calcareous bands at top (lot 9917)	20–25
3. Hard black slate with occasional thin bands of dark limestone	150

Triassic rocks were discovered by Kirk near Carroll Island, on Pybus Bay, between Gambier Bay and the small cove south of False Point Pybus, and on Mole Harbor. Fossils from these localities are listed in the table below, and the available information concerning their occurrence is given in the accompanying description of localities.

Age and correlation.—The Triassic rocks of Admiralty Island have yielded the fossils listed in the following table:

Triassic fossils from Admiralty Island [a]

	10195	8847	8848	8849	9117	10180	10172	10194	10171	10196	10168
Terebratula									×		
Nucula			×								
Pseudomonotis subcircularis (Gabb)										×	×
Halobia cf. H. superba Mojsisovics	×	×		×	×	×		×			
Halobia			×								
Gryphaea									×		
Myophoria							×				
Undetermined pelecypods					×						
Undetermined gastropod							×				
Discotropites						×					
Juvavites			×								
Juvavites ?						×			×		
Clionites							×		×		
Arcestes			×			×					
Atractites					×						
Atractites ?						×					
Undetermined ammonites			×		×						
Undetermined spherical bodies										×	

[a] Identified by T. W. Stanton.

10195. South of Carroll Island. Argillite and sandstone. Edwin Kirk, 1918.

8847. Point at north entrance to Herring Bay, Admiralty Island. Bed No. 11 of section on page 90. Martin and Overbeck, 1914.

[88] Wright, C. W., op. cit., p. 143.

8848. Point at north entrance to Herring Bay, Admiralty Island. Bed No. 9 of section on page 90. Martin and Overbeck, 1914.

8849. Point at north entrance to Herring Bay, Admiralty Island. Bed No. 4 of section on page 90. Martin and Overbeck, 1914.

9117. 1 mile east of Herring Bay, Admiralty Island. "Thin fossiliferous calcareous bands at top of a coarse conglomerate." E. M. Kindle, 1905.

10180. Point between Chapin Bay and Herring Bay. Edwin Kirk, 1918.

10172. South point of V-shaped bay just south of False Point Pybus. Edwin Kirk, 1918.

10194. About half a mile north of False Point Pybus. Edwin Kirk, 1918.

10171. East side of Church Point south of Gambier Bay. Edwin Kirk, 1918.

10196. North shore of east arm of Pybus Bay. Limestone overlying Carboniferous (?) conglomerate. Edwin Kirk, 1918.

10168. West side of Mole Harbor. Edwin Kirk, 1918.

These fossils indicate, for most of the localities, the well-known Karnic fauna with *Halobia* cf. *H. superba* and its characteristic ammonites. The younger *Pseudomonotis* horizon of the Noric is indicated at two localities. It is noteworthy that one of these (No. 10196, on Pybus Bay) is very close to the base of the local Triassic section, which may be a further indication of an unconformity at the base of the *Pseudomonotis*-bearing beds. No information concerning the occurrence of *Pseudomonotis* at Mole Harbor is available.

GASTINEAU VOLCANIC GROUP OF THE JUNEAU DISTRICT

Historical review.—The andesitic Gastineau volcanic group of Eakin and Spencer [89] is the lower volcanic part of the "slate-greenstone band" earlier described and mapped by Spencer [90] and part of the rocks which he mapped as "greenstone." [91] Spencer's early description of these rocks includes a brief general account of the character and occurrence of the "slate-greenstone band" with more specific description of some of the constituent rock types. He referred the "slate-greenstone band" to the Carboniferous on the basis of a correlation of some of its limestone with the fossiliferous Carboniferous limestone of Taku Harbor. The Gastineau volcanic group forms part of the rocks within the Juneau district which Knopf [92] mapped as "greenstones" but which he did not differentiate from the other volcanic rocks of the region and which he did not describe. It may possibly be represented in the "altered amygdaloidal basalts," near Berners Bay, which Knopf [93] described.

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[89] Eakin, H. M., and Spencer, A. C., Geology and ore deposits of Juneau, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[90] Spencer, A. C., The Juneau gold belt, Alaska: U. S. Geol. Survey Bull. 287, pp. 16–18, pl. 37, 1906.

[91] Idem, pl. 4.

[92] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pl. 5, 1912.

[93] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, pp. 13, 19–21, pl. 2, 1911.

Eakin and Spencer's description of the Gastineau volcanic group [94] includes a general account of the character of the rocks and a discussion of their age, with lists of Triassic fossils identified by Reeside from material collected by Eakin and Spencer. The geologic map shows the distribution of the beds represented in the section below, but these beds are not described individually in the text.

Stratigraphic description.—The general sequence of rocks in the Juneau district, according to Eakin and Spencer, is represented in the following table, in which the age assignments are those of the writer:

Stratigraphic section near Juneau

Upper Jurassic (?):
- Douglas Island volcanic group (melaphyre flows, tuff, and agglomerate).
- Treadwell slate (black clay slate with some conglomerate and considerable graywacke).

Lower or Middle Jurassic (?):
- Thane volcanic group:
  - Melaphyre tuff.
  - Limestone.
  - Tuff and slate.

Upper Triassic:
- Gastineau volcanic group:
  - Slate.
  - Andesitic tuff.
  - Calcareous slate with Upper Triassic fossils.
  - Andesitic lava, with local lenses of slate.

Triassic or older:
- Perseverance slate (clay slate).

Paleozoic, with possibly some infolded Triassic:
- Clark Peak schist (schistose rocks derived from slate, sandstone, limestone, and conglomerate).

This section represents the present sequence of rocks from a point near the crest of Douglas Island (top of section) to the western margin of the granite mass of the Coast Range east of Juneau (base of section). It has been assumed that the present sequence of the rocks from west to east is their normal stratigraphic sequence from top to base—that is, the rocks now lie in their original stratigraphic sequence with no structural disturbance except for minor crumpling and faulting, which have not affected the sequence of the beds, and for a general overturn of the entire section. It is entirely possible, in the writer's opinion, that there may be undetected faults and close folds which have caused gaps, repetitions, and local overturns within this section. No indication of any such

[94] Eakin, H. M., and Spencer, A. C., op. cit.

disturbances has been found, but if such disturbances were present they would be very difficult to detect.

There is no conclusive evidence on the age of any of the rocks at Juneau, except for the slate in the Gastineau volcanic group, which has yielded characteristic Upper Triassic fossils. The other beds have yielded no fossils, and there is only indirect and inconclusive evidence on their age.

The Gastineau volcanic group is composed of andesitic lava and tuff interbedded with calcareous slate that contains Upper Triassic fossils. It is overlain by the Thane volcanic group, which is composed largely of melaphyre tuff interbedded with slate and limestone. The Thane group has yielded no fossils, but in its lithologic character and stratigraphic relations it seems to correspond to some of the early Jurassic rocks of other regions. It will accordingly be described (pp. 251–252) as probably Lower or Middle Jurassic.

The Gastineau volcanic group consists of andesitic lava at the base with local lenses of slate, overlain by calcareous slate containing marine Upper Triassic fossils, above which is andesitic tuff overlain by slate. The thickness of this group is possibly about 5,000 feet.

Beneath the Gastineau volcanic group is the Perseverance slate, consisting of unfossiliferous clay slate, possibly 3,000 feet thick. The Perseverance slate may perhaps be Triassic and was regarded by Eakin and Spencer as probably Triassic because it is apparently conformable with the overlying Gastineau volcanic group. As it does not appear to correspond in character and position with any of the known Triassic rocks of other parts of Alaska, however, the writer doubts its Triassic age. The Clark Peak schist, which underlies the Perseverance slate was also regarded by Eakin and Spencer as probably Triassic, but as it does not bear a notable resemblance to any known Triassic rocks and as it lies on the strike of the Carboniferous rocks of Taku Harbor and other localities south of Taku Inlet, the writer believes that it belongs in the Paleozoic, where it was formerly placed by Spencer.[95] It may, however, include some infolded Triassic beds.

Age and correlation.—The Upper Triassic age of the Gastineau volcanic group is shown by the fossils listed on page 95. The presence of *Halobia* cf. *H. superba* indicates a position approximately equivalent to that of most of the other Triassic rocks of southeastern Alaska.

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95 Spencer, A. C., The Juneau gold belt, Alaska: U. S. Geol. Survey Bull. 287, 1906.

Fossils from the Gastineau volcanic group [a]

	9844	9845	9846
Halobia cf. H. superba Mojsisovics	------	×	×
Arcestes or Paraganides	×	------	------
Trachyceras (Protrachyceras) lecontei Hyatt and Smith?	×	------	------
Atractites cf. A. phillippi Hyatt and Smith	------	×	------
Undetermined ammonite	------	×	------

[a] Identified by J. B. Reeside, jr.

9844. Middle Peak on Sheep Creek-Grindstone divide. H. M. Eakin, 1916.
9845. Head of Sheep Creek near Goldstein divide. A. C. Spencer, 1916.
9846. Sheep Creek basin, head of west tributary. A. C. Spencer, 1916.

YUKON VALLEY

The only known Triassic rocks in the Yukon Valley are near the mouth of Nation River, not far below the Canadian boundary, and possibly in the Kantishna district.

LIMESTONE NEAR NATION RIVER

Historical review.—The presence of Triassic rocks on Yukon River was first noted by Brooks and Kindle,[96] who gave a brief description of the occurrence of fossiliferous Triassic beds near the mouth of Nation River, together with a general discussion of the other Triassic occurrences in Alaska and Yukon Territory. This description of the Nation River occurrence was in part quoted by Prindle,[97] who added no new data, the occurrence being outside of the area that he described. The Triassic localities near Nation River were visited in 1914 and 1919 by the writer, who has given a brief description of the rocks with a stratigraphic section and a discussion of the faunas.[98]

Stratigraphic description.—The Upper Triassic rocks near Nation River consist of thin-bedded limestone and calcareous shale at least 400 feet thick, resting with probable unconformity though without marked discordance of bedding upon upper Carboniferous limestone. The top of the Triassic rocks has not been observed, but as the next younger rocks known in this region are Lower Cretaceous the upper contact is probably marked by a profound unconformity. The Cretaceous and the Triassic rocks, so far as known, however, do not crop out in contact.

These Triassic rocks are exposed on the south or left bank of the Yukon about a mile above the mouth of Nation River. The Triassic

[96] Brooks, A. H., and Kindle, E. M. Paleozoic and associated rocks on the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 262, 297, 304–305, 313, 1908.

[97] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, p. 30, 1913.

[98] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 701–702, 708, 1916.

exposures consist of small discontinuous outcrops on the river bank just north of a series of cliffs containing upper Carboniferous limestone. Both the Triassic and the Carboniferous rocks dip northward, or downstream, with approximately parallel bedding. The highest of the recognized Carboniferous strata is a bed of yellowish subcrystalline limestone with *Productus* and other brachiopods and corals, indicating a very high Carboniferous fauna corresponding to the Artinskian of Europe.

Section of Upper Triassic strata on south bank of Yukon River 1 mile above Nation River

	Feet
Calcareous shale and shaly limestone with *Pseudomonotis subcircularis* (Gabb), *Rhynchonella?* sp., and *Terebratula* sp	20+
Calcareous shale and shaly limestone with *Halobia* cf. *H. superba* Mojsisovics, *Pleurotomaria?* sp., and *Clionites?* sp	320
Limestone with *Rhynchonella* sp., *Terebratula* sp., *Spiriferina* sp., *Halobia* sp., *Aviculipecten* sp., *Pecten* sp., *Pleurophorus?* sp., *Natica?* sp., *Orthoceras* sp., *Nautilus* sp., *Popanoceras* (*Parapopanoceras*)? sp., *Monophyllites?* sp., *Placites?* sp., and *Trachyceras* (*Protrachyceras*)? cf. *T. lecontei* Hyatt and Smith	60
Underlain unconformably (?) by lower Permian (?) limestone with an Artinskian fauna.	

About 50 feet above the uppermost exposed bed of Carboniferous limestone and separated from it by a concealed interval is a 10-foot bed of dark noncrystalline limestone which is probably Triassic. The bedding of this stratum is approximately parallel to that of the underlying Carboniferous limestone. The difference in degree of crystallinity is a possible indication of an unconformity, although this difference may be due to a difference in composition or to local deformation or local water channels. This bed of limestone yielded the fossils contained in lot 8895. These fossils have been examined by T. W. Stanton, who decided that they are "probably Triassic" and identified the genera listed in the table on page 98.

The succeeding section, exposed farther down the river bank, is incomplete but apparently consists chiefly of calcareous shale and shaly limestone. These beds contain characteristic Upper Triassic fossils, of which lot 8896 was obtained about 30 feet above the somewhat doubtful bed that yielded lot 8895, and lot 8897 was obtained about 10 feet still higher. These two lots contain *Halobia* cf. *H. superba* Mojsisovics and consequently indicate a horizon corresponding approximately to that of part of the Chitistone limestone. The northernmost of the observed Triassic exposures, which is about 300 feet still higher, or about 400 feet above the highest recognized Carboniferous bed, yielded lot 8899, which contains *Pseudomonotis subcircularis* (Gabb). It consequently indicates a horizon corresponding approximately to that of the McCarthy formation, which

is the equivalent of the highest recognized marine Triassic horizon of America.

The Triassic rocks described by Brooks and Kindle are exposed on the hill slope about a quarter of a mile northeast of Nation River, on the north or right side of the Yukon. They consist, according to Kindle's field notes, of

heavy and thin bedded dark-gray limestone, shaly at the top, of which 15 or 20 feet is exposed. Sandy shale is seen at the top of the limestone, and the interval between this limestone and locality No. 15 [upper Carboniferous] is covered but is probably mostly shale. The interval is about 500 or 600 feet.

According to the published description,[99]

This fauna occurs in a limestone exposing about 15 feet at the outcrop. The limestone apparently belongs in a shale and sandstone series immediately following the upper Carboniferous limestone, which is but slightly exposed where the collection was made. Our very limited knowledge of this terrain makes it impossible to offer any estimate of the thickness of the beds which should be assigned to it.

The fossils from this locality are included in lot 4054, which, according to Stanton,

contains many specimens of *Halobia* cf. *H. superba* Mojsisovics, and on the evidence of this species it was referred to the Triassic. The lot also contains, in limestone of somewhat different texture, many other small fossils among which Girty made the following tentative generic reference. [See lot 4054a, p. 99.] This fauna is practically duplicated in 8895, which was collected by Martin in the same neighborhood. The natural inference from Kindle's collection is that this fauna occurs in a bed intercalated among those containing *Halobia*, while Martin's collection indicates that it comes from beds lower than the *Halobia* horizon. The question of age must still be left open.

The *Rhynchonella* [of lot 8895] is the same as *Pugnax* of Girty's tentative list based on Kindle's collection (4054), and the *Terebratula* is the same as the *Dielasma?* of the same list. Leffingwell got similar, possibly identical brachiopods at his locality 17 on Canning River.

Upper Triassic rocks were seen also on Trout Creek, which enters the Yukon about 2 miles below the old Montauk roadhouse, or about 6 miles above Nation River. The Triassic rocks are exposed about 3 miles above the mouth of the creek. They consist of thin-bedded shaly limestone, possibly several hundred feet thick, which is apparently underlain by Carboniferous limestone and is apparently overlain by gravel that is believed to be derived from decayed Upper Cretaceous or Tertiary conglomerate.

Age and correlation.—Three more or less distinct faunal zones are indicated by the fossils from the Triassic rocks near Nation River. The fauna of the lower limestone differs strikingly from any of the Triassic faunas recognized in the southern part of Alaska. Its Upper Triassic age is indicated by the ammonites doubtfully identi-

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[99] Brooks, A. H., and Kindle, E. M., op. cit., p. 304.

fied as *Monophyllites*, *Placites*, and *Trachyceras* (*Protrachyceras*) *lecontei*. The ammonite doubtfully identified as *Popanoceras* (*Parapopanoceras*) sp. is suggestive of the Middle Triassic, but as it is an immature specimen its evidence is inconclusive and is overbalanced by that of the other fossils. The fauna differs strikingly from that of the Chitistone limestone and supposedly equivalent beds of the southern part of Alaska in the absence of such characteristic fossils as *Tropites*, *Juvavites*, *Arcestes*, and *Halobia* cf. *H. superba* and in the abundance of brachiopods and nautiloids. Its nearest relations among known Alaskan faunas are a fauna found on Canning River, with which it has several species in common, and possibly some of the collections from Hamilton Bay on Kupreanof Island.

The calcareous shale and shaly limestone, with *Halobia* cf. *H. superba*, *Pleurotomaria?*, and *Clionites?*, which overlie the limestone just discussed and make up the greater part of the section exposed at this locality, are to be correlated approximately with the Chitistone limestone, although their fauna also differs from those of southern Alaska and resembles that of Canning River in the absence of the common ammonites of the southern region and in the probable presence of *Clionites*. The beds at the top of the section, containing *Pseudomonotis subcircularis* (Gabb), represent the boreal Upper Noric horizon of the McCarthy formation.

Fossils from Triassic limestone near Nation River[a]

	8895	9384	9385	9386	4054a	4054b	9387	9388	8896	8897	8898	9383	8899	9382	10266	10267	9321
Coral? (doubtfully organic)				a													
Rhynchonella	a	a	a		b												
Rhynchonella?	a													a			
Camarophoria?					b												
Martinia?					b												
Terebratula	a				b									a			
Spiriferina	a	a	a		b												
Nucula					b												
Pseudomonotis subcircularis (Gabb)													a	a			
Pseudomonotis (apparently distinct from subcircularis)															a	a	a
Halobia cf. H. superba Mojsisovics						a		a	a	a	a	a			a	a	
Halobia	a																
Halobia?		a															
Aviculipecten	a		a		b												
Aviculipecten?		a	a														
Pecten		a															
Modiomorpha?					b												
Pleurophorus?		a															
Plagioglypta?					b												
Pleurotomaria?							a										
Natica?	a																
Orthoceras		a	a														
Nautilus	a	a	a														
Popanoceras (Parapopanoceras) ? (immature specimen)			a														
Monophyllites?		a															
Placites?			a														
Clionites?							a				a						
Trachyceras (Protrachyceras) ? cf. T. lecontei Hyatt and Smith			a														
Undetermined ammonite	a																
Bone (fragment)							a										

[a] a, Identified by T. W. Stanton; b, identified by G. H. Girty.

8895. South bank of Yukon River, about 1 mile above Nation River. Ten-foot bed of dark noncrystalline limestone which is probably not more than 50 feet (unconformably?) above the crystalline Carboniferous limestone. Martin and Overbeck, 1914.

9384. South bank of Yukon River, about 1 mile above Nation River. Same locality and bed as 8895. Eliot Blackwelder, 1915.

9385. Hillside about one-third of a mile northeast of the mouth of Nation River. Probably same bed as 9384 and apparently near the same locality and bed as 5054. Eliot Blackwelder, 1915.

9386. Hillside about one-third of a mile northeast of the mouth of Nation River. Same locality as 9385, but top of 25-foot limestone (upper part of same bed). Eliot Blackwelder, 1915.

4054a. Mountain north of Yukon River, about a quarter of a mile northeast of the mouth of Nation River. Fifteen-foot bed of limestone in a shale and sandstone series. E. M. Kindle, 1906.

4054b. Same locality as 4054a, but limestone of somewhat different texture. E. M. Kindle, 1906.

9387. Hillside about one-third of a mile northeast of the mouth of Nation River. Shale about 25 feet above 9385. Eliot Blackwelder, 1915.

9388. Hillside about one-third of a mile northeast of the mouth of Nation River. Black shaly limestone about 15 feet above 9387. Eliot Blackwelder, 1915.

8896. South bank of Yukon River, about 1 mile above Nation River, a short distance downstream from 8895. About 30 feet above 8895, in a series of calcareous shale and shaly limestone. Martin and Overbeck, 1914.

8897. South bank of Yukon River, about 1 mile above Nation River. About 10 feet above 8896. Martin and Overbeck, 1914.

8898. South bank of Yukon River, about 1 mile above Nation River. Float from river bank between 8897 and 8899. Martin and Overbeck, 1914.

9383. South bank of Yukon River, about 1 mile above Nation River. Calcareous shale and shaly limestone about 260 feet above 9384. Eliot Blackwelder, 1915.

8899. South bank of Yukon River, about 1 mile above Nation River, downstream from 8897. About 300 feet (stratigraphically) above 8897. Martin and Overbeck, 1914.

9382. South bank of Yukon River, about 1 mile above Nation River. Calcareous shale and shaly limestone about 350 feet above 9384. Eliot Blackwelder, 1915.

10266. Trout Creek, tributary to Yukon River from the south about 2 miles below old Montauk roadhouse, about 3 miles above mouth of creek. Shaly limestone. G. C. Martin, 1919.

10267. Same locality as 10266. G. C. Martin, 1919.

9321. Trout Creek, about 4 miles from mouth. Probably same locality as 10266. Preston J. Hilliard, 1915.

TRIASSIC (?) LIMESTONE OF THE KANTISHNA DISTRICT

The supposed Triassic rocks of the Kantishna district were described by Capps[1] as consisting of black siliceous limestone that contains imperfectly preserved corals. The limestone occurs near the headwaters of Sushana River in close association with the slates

[1] Capps, S. R., The Kantishna region, Alaska: U. S. Geol. Survey Bull. 687, pp. 32, 33, 37, 1919.

and phyllites of the Tonzona group which were considered by both Capps and by Brooks[2] as probably Silurian or Devonian. Capps believes that the limestone is not a member of the Tonzona group but that it has been folded or faulted into its present position. It is possible, however, that the Tonzona group may itself be Mesozoic. No other Mesozoic rocks have been found in or near the Kantishna district. The following statement was made by Stanton[3] concerning the fossils collected by Capps in 1916:

10031 (No. 2). At extreme head of Sushana River. This lot contains a few imperfectly preserved corals which seem to be of Mesozoic types, though it has not been possible to identify them even generically. They are similar to corals obtained in Triassic limestones in other Alaskan areas, and it is most probable that these are of that age. Messrs. Kirk and Girty, who have examined the corals, both are of the opinion that they are not Paleozoic forms.

ARCTIC SLOPE

GENERAL FEATURES

The Upper Triassic rocks of the Arctic slope of Alaska are known in two districts—in the Firth Valley, near the international boundary, and in the vicinity of Canning River, about 130 miles west of the boundary. The Triassic rocks of these two districts are very much alike in lithologic character, consisting mostly of limestone and shale, and are probably alike also in their relation to the underlying and overlying formations. The Triassic beds of Firth River are underlain by upper Carboniferous limestone. The Triassic beds of Canning River are clearly underlain by upper Carboniferous sandstone and overlain by lower Jurassic shale. In the Firth Valley the top of the Triassic rocks has not been recognized because of complex structure. The presence of a lower Jurassic fauna similar to that of Canning River is indicated by fossils that have been found in this district, and consequently there is little doubt that the Upper Triassic rocks of Firth River resemble those of Canning River in being overlain by Middle or Lower Jurassic strata. It is also highly probable that the Triassic rocks of these two districts occur in the same structural belt, and it is possible that the Triassic rocks are exposed continuously from one section to the other.

SHALE AND LIMESTONE OF FIRTH RIVER

Historical review.—Upper Triassic rocks were discovered by A. G. Maddren in the Firth Valley near the international boundary. These

[2] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 73–76, 1911.
[3] Stanton, T. W., cited by Capps, S. R., op. cit., p. 33.

occurrences have been briefly described by Maddren.[4] A brief account of these rocks has also been given by Martin.[5]

Stratigraphic description.—The Upper Triassic rocks of the Firth Valley consist of impure limestone and sandy shale having a thickness of at least several hundred and possibly a thousand feet or more. They are closely associated with upper Carboniferous limestone, which is in places folded or faulted over them. On account of the structural conditions the character of the basal contact of the Triassic beds is not known, nor has the thickness been determined with certainty. The top of the Triassic rocks has also, for the same reason, not been recognized. It is probable, however, that the succeeding formation is a Middle or Lower Jurassic limestone, which is now complexly infolded with the Triassic beds so that it has not been differentiated, although its presence (see pp. 264–265) has been recognized from fossils.

The Triassic shale and limestone of Firth River have been described by Maddren[6] as follows:

> Several miles south of the northern border of the Carboniferous rocks just described and about 8 miles west of the 141st meridian marine fossils of Upper Triassic age occur in a formation that is made up largely of black shales and impure thin-bedded shaly limestones but possibly contains some massive limestones. This formation appears to be involved by profound folding and possibly faulting with the intimately associated Carboniferous limestones in such a manner that its position is now apparently beneath the older formations. At least, this is the tentative view now held as a result of the preliminary examination made in 1911.
>
> Similar Upper Triassic rocks are situated approximately 1 mile west of the 141st meridian about 5 miles south of the upper Firth River basin or Valley of Three Rivers. These are likewise associated with the massive Carboniferous limestone series and in the field examination of 1911 were considered possibly to underlie them. The outcrops from which the Triassic fossils were obtained are poorly exposed beds of impure flaggy limestone interbedded with sandy shales, which have not been observed in contact with the older series. They lie in the wide valley head of one of the extreme northern headwaters of Old Crow River. These rocks were not recognized elsewhere in this basin by fossils, but some black limy shales of somewhat similar appearance occur along the foot of the eastern slopes of the basin several miles to the southwest.

Age and correlation.—Two faunal zones are indicated by the fossils that have been collected from these rocks. The older zone contains *Halobia* cf. *H. superba* Mojsisovics and other pelecypods, which have been found in beds of flaggy limestone interbedded with sandy shale on the international boundary about 80 miles north

[4] Maddren, A. G., Geologic investigations along the Canada-Alaska boundary: U. S. Geol. Survey Bull. 520, pp. 300, 312–313, 1912.

[5] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 702–703, 1916.

[6] Madden, A. G., op. cit., pp. 312–313.

of Porcupine River (lots 7380 and 7381, below). A younger zone is indicated by the presence (lot 7382) of *Pseudomonotis subcircularis* (Gabb) in limestone beds west of the boundary and about 28 miles farther north. The relation of the beds at these two localities to each other is not known. The *Pseudomonotis*-bearing beds occur on the contact with upper Carboniferous rocks which are apparently folded or faulted over them. Another collection (lot 8207) contains both *Halobia* and *Pseudomonotis*. As this lot, when received, included some crinoids that are probably Lower Jurassic (see p. 265), as well as some upper Carboniferous fossils contained in limestone which, according to Stanton, "differs in color and other characters from the limestone containing the Triassic fossils," and as according to Maddren's field notes, "about 1,000 feet of Triássic beds appear to be involved in the exposure, but much of this is composed of dark shale too much crumpled to be deciphered with satisfaction at this locality," it is obvious that this collection does not prove that the *Halobia* and the *Pseudomontis* lived in the same sea.

It may be that in parts of the Alaskan Triassic seas *Halobia superba* and *Pseudomonotis subcircularis* had a different range and distribution from that which their kindred species are supposed to have had in the European and Californian Triassic, where the *Halobia* is supposed to be a warm-water Karnic species and the *Pseudomonotis* a cold-water Noric species, but this occurrence does not prove that such is the case. It is possible that here, as at some of the other Alaskan localities where these forms seem to be in the same beds, the apparent facts may be explained by mixed collections, by structural conditions, or by unrecognized specific differences.

Upper Triassic fossils from Firth River[a]

	7380	7381	7382	8207
Rhynchonella				×
Avicula		×		
Pseudomonotis subcircularis (Gabb)			×	×
Halobia cf. H. superba Mojsisovics	×	×		×
Ostrea?		×		
Pecten		×		
Pecten?				×
Pleuromya?				×
Californites? (young specimen)				×

[a] Identified by T. W. Stanton.

7380. About a mile west of heliograph station T, on international boundary 80 miles north of Porcupine River. Impure flaggy limestone interbedded with the sandy shale that yielded lot 7381. A. G. Maddren, 1911.

7381. Same locality as 7380. Sandy beds. A. G. Maddren, 1911.

7382. About 1½ miles up a gulch southwest of west camp on West Fork of Firth River, about 6½ miles west of international boundary and 108 miles north of Porcupine River. Ferruginous limestones apparently near base of the

limestone that forms the ridge along the south side of the West Fork. The Carboniferous is apparently folded over the Triassic at this point. A. G. Maddren, 1911.

8207. About 100 to 500 feet above mouth of a south-side gulch, tributary to Overthrust Creek, 1¾ miles above its mouth. About 8 miles west of the international boundary, in latitude 68° 56′ 10″ N. Thin dark brittle limestone alternating with crumpled dark calcareous and ferruginous sandy shale. A. G. Maddren, 1912.

SHUBLIK FORMATION

Historical review.—Upper Triassic rocks are well exposed in the vicinity of Canning River on the Arctic slope about 130 miles west of the international boundary. This occurrence was discovered and has been investigated in detail by E. de K. Leffingwell in the course of his extensive explorations of the north coast and Arctic slope of Alaska. These Triassic rocks were described by Leffingwell[7] as the Shublik formation, and his account included a detailed description of the formation with lists of fossils as determined by T. W. Stanton. The fauna of the Shublik formation has been discussed by Martin.[8]

Stratigraphic description.—The Shublik formation, as described by Leffingwell, is exposed along the northern front of the Franklin Mountains on the tributaries of Canning and the neighboring rivers. The type locality is at Shublik Island, in Canning River. This formation consists of dark limestone, shale, and sandstone and is probably about 500 feet thick. It includes at least three characteristic members—a lower member, about 30 feet thick, composed of calcareous sandstone; a middle member, about 100 feet thick, composed of limestone with some interbedded shale; and an upper member, about 100 feet thick, composed of black shale. Between these recognized members are concealed intervals of unknown character and extent. The Shublik formation overlies the upper Carboniferous (Pennsylvanian) rocks of the Sadlerochit formation, and is overlain by the Middle or Lower Jurassic Kingak shale, which is described on page 263. Neither the lower nor the upper contact has been observed in detail, but both contacts are apparently conformable.

Age and correlation.—The fauna of the Shublik formation, as represented in the following table, includes fossils from all three of the characteristic members described above. The lower sandstone member is represented by 10294; the middle limestone member by 10297, 10300, 10302, 10303, 10305, and 10310; and the upper shale member by 10299 and 10301. The remaining collections came from unknown beds. The brachiopods of 10297, according to T. W. Stan-

[7] Leffingwell, E. de K., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, pp. 103, 115–118, pl. 2, 1919.

[8] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, p. 703, 1916.

ton, "suggest a fauna closely related to the somewhat doubtful Triassic fauna collected near the mouth of Nation River on the Yukon." (See lots 4054 and 8895, p. 98.)

Fossils from the Shublik formation [a]

	10294	10297	10300	10302	10303	10304	10305	10310	10295	10296	10298	10313	10314	10315	10316	10299	10301	10301'
Rhynchonella	--	×	×	×	--	×	--	--	×	×	×	×	×	--	--	--	×	×
Rhynchonella (2 species)	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Rhynchonella?	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
Terebratula	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--
Terebratula (2 species)	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Spiriferina	--	×	--	--	--	×	--	--	--	--	--	×	--	--	--	×	--	--
Spiriferina?	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nucula?	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gervillia	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Gervillia? (very small specimen)	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Avicula	--	×	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--
Pseudomonotis subcircularis (Gabb)	--	--	--	--	--	×	--	--	--	--	--	--	--	×	--	--	--	--
Pseudomonotis subcircularis?	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×
Pseudomonotis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--
Pseudomonotis?	--	--	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--
Halobia cf. H. superba Mojsisovics	--	--	--	--	×	×	--	×	--	--	×	--	--	--	--	×	×	--
Halobia	--	-	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--
Gryphaea?	--	--	--	--	--	×	--	×	--	--	--	--	--	--	--	--	--	×
Gryphaca?	--	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--
Megalodon?	--	×	--	--	--	×	--	--	--	--	×	--	--	--	--	--	--	--
Aviculipecten	--	--	×	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Pecten	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lima	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--
Lima? (large form)	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lima? (small fragments)	--	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Cardium?	×	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Pleurotomaria	--	×	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--
Pleurotomaria?	--	--	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--
Natica?	--	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--
Undetermined gastropods (small)	--	--	--	--	--	--	--	×	--	--	--	--	--	--	--	--	--	--
Clionites?	--	--	--	--	--	--	--	×	--	--	--	×	--	--	--	--	--	--
Atractites?	--	--	--	--	--	×	--	×	--	--	--	×	--	--	--	--	--	--
Bone fragments	--	--	--	×	--	--	--	--	--	--	--	--	--	--	--	--	--	--

[a] Identified by T. W. Stanton.

10294 (6). Canning River, near top of Red Hill at camp 146. Isolated outcrop of dark sandstone, of which 10 feet is exposed. Lower sandstone member of formation. E. de K. Leffingwell, 1908.

10297 (17). Canning River, cut half a mile above camp 152, on north side of Ikiakpaurak Creek. Top of anticline, within 1 or 2 feet of a single bed, in hard dark limestone, of which 50 feet is exposed. E. de K. Leffingwell, 1908.

10300 (22A). Canning River, half a mile east of No. 21, on the south side of the river. Top of a 35-foot bed of dark limestone which is overlain by 100 feet of soft black shale. E. de K. Leffingwell, 1908.

10302 (30). Canning River. Cut on creek about half a mile above camp 149. About 100 feet of dark limestone exposed. E. de K. Leffingwell, 1908.

10303 (30A). Canning River, same locality as No. 30 but top of exposure. E. de K. Leffingwell, 1908.

10304 (30B). Canning River, talus below 30A. E. de K. Leffingwell, 1908.

10305 (30C). Canning River, same locality as No. 30 but bottom of exposure. E. de K. Leffingwell, 1908.

10310 (115B). Sadlerochit River, Camp 263 Creek, near the mountains. Outcrop of 12 feet of dark limestone, probably about 80 feet below the top of the limestone member of the formation. E. de K. Leffingwell, 1910–1912.

10295 (13). Canning River. Float from creek near camp 149. E. de K. Leffingwell, 1908.

10296 (15). Canning River. Outcrop across creek from camp 150. E. de K. Leffingwell, 1908.

10298 (18). Canning River. Isolated outcrop at base of hogback 2 miles east of camp 152, on north side of creek. E. de K. Leffingwell, 1908.

10313. Hulahula River, fishing place at edge of mountains. Collected in winter from scattered outcrops along the river. E. de K. Leffingwell, 1910–1912.

10314. Shublik Falls, Canning River. Collected in winter from scattered outcrops along the river. E. de K. Leffingwell, 1910–1912.

10315. Sagavanirktok River. Slab collected by natives. E. de K. Leffingwell, 1910–1912.

10316. Black Island, Canning River, near Shublik Falls. E. de K. Leffingwell, 1910–1912.

10299 (21). Canning River, cut on south side of Ikiakpaurak Valley 1 mile above camp 152. Bottom of exposure of 100 feet of fissile black shale. E. de K. Leffingwell, 1908.

10301 (22C). Canning River, same locality as 22A, but from 1 to 3 feet of black shale 30 feet above 22A. About the same horizon as No. 21. E. de K. Leffingwell, 1908.

10301′ (22C′). Canning River, same locality as 22C, but from a talus block immediately below 22C. E. de K. Leffingwell, 1908.

The fauna of these rocks is certainly Upper Triassic, as is shown by the presence of *Clionites* and *Halobia* cf. *H. superba Mojsisovics.* The presence of the *Halobia* suggests a position in the middle or Karnic stage of the Upper Triassic, corresponding approximately to the horizon of the Chitistone limestone. The association of such genera as *Megalodon?* and *Aviculipecten*, which are not known from rocks younger than the Triassic, with such genera as *Gervillia*, *Gryphaea*, *Cardium*, *Natica*, and *Atractites*, which are not known from rocks older than the Triassic, would in itself indicate the Triassic age of this fauna. This fauna differs from the better-known Triassic faunas of the southern part of Alaska in the entire absence of the corals and of such pelecypods as *Myophoria* and *Pleuromya* and in the practical absence of the ammonites, especially such ammonite genera as *Tropites*, *Juvavites*, and *Arcestes*, which are very abundant in most of the Triassic areas of southern Alaska. It differs also from the other known Alaskan Triassic faunas in the preponderance of the brachiopods and in the presence of *Gervillia* and *Megalodon?*, and it differs from most of the others in the presence of *Clionites*. The Alaskan fauna most closely related to this occurs in the lowest bed of the Triassic limestone near Nation River.

The presence of *Pseudomonotis subcircularis* (Gabb) in talus and float material at several localities in the Canning River district indicates the presence of beds corresponding to those of the McCarthy formation. The *Pseudomonotis* zone from which this material was derived may occur either in the uppermost part of this formation or in a thin overlying formation that has not been recognized.

NOATAK VALLEY

CHERTY LIMESTONE FLOAT

The presence of Upper Triassic rocks in the Noatak Valley is indicated by a boulder containing well-preserved specimens of *Pseudomonotis subcircularis* (Gabb) in the gravel of Noatak River. The fossils, according to Philip S. Smith,[9] who found them, occur in masses of black chert contained in dark thin-bedded limestone. The rocks that crop out in the vicinity consist of dark limestone that is practically indistinguishable in lithologic character from the Triassic boulders but has been considered a member of the Noatak sandstone, of lower Carboniferous (Mississippian) age. It was the opinion of Smith that the Triassic boulders had probably not been transported far, but that they might possibly have come from a considerable distance. The river gravel contains boulders with Carboniferous fossils and also some that are possibly Devonian. It seems possible that there may be a large area of Triassic rocks where the fossils were found, the neighboring outcrops consisting of Triassic limestone rather than being members of the Noatak sandstone, as Smith considered them, and the Carboniferous float being brought down from the hills to the north. It is also possible that all the neighboring rocks are Carboniferous and that the Triassic float was brought in from a distance. A third possibility is that the Carboniferous and the Triassic rocks are both present near this locality, but that they occur in such intimate stratigraphic or obscure structural relations that they have not been differentiated.

The age of the fossiliferous cherty limestone was determined by T. W. Stanton, who states:

7244. No. 11 AS 44; Noatak River at first stream from south, west of the camp of August 8, approximately latitude 68° N., longitude 159° W.:

Pseudomonotis subcircularis (Gabb).

Upper Triassic. The collection contains only a single species, but it is represented by a number of well-preserved specimens and is a widely distributed and very characteristic form found thus far only in the Upper Triassic.

NORTHWESTERN ALASKA

GENERAL FEATURES

The known Triassic rocks of the extreme northwestern part of Alaska include chert, shale, and thin-bedded limestone exposed in several areas near Cape Lisburne and in an area about 55 miles farther south, near Cape Thompson. The Triassic rocks of Cape Lisburne and Cape Thompson not only are practically identical in

[9] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp. 79–80, 1913.

lithologic and faunal character but apparently occur in very similar stratigraphic relations to the associated formations.

The general character, sequence, and relations of the rocks in the vicinity of Cape Lisburne were represented by Collier [10] as follows:

Tabular statement of stratigraphy, Cape Lisburne region, Alaska

Age	Formation	Contact relations	Thickness (feet)	Lithologic character
Recent.		Unconformity.	50+	Sands, gravels, etc.
Pleistocene.		Unconformity.	50+	Gravels, silts, talus, and ground ice.
Lower Cretaceous (?).		Conformity.	10,000+	Sandstones interbedded with shales. Nonfossiliferous.
Upper Jurassic.	Corwin.	Unconformity.	15,000+	Calcareous and carbonaceous shales with sandstones and conglomerates at infrequent intervals. Many coal beds. Jurassic plants. No marine fauna.
Lower Carboniferous (Mississippian).	Lisburne.	Conformity.	3,000+	(*a*) Massive limestones interstratified with white cherts. Extensive coral and bryozoan fauna.
		Conformity.	1,000+	(*b*) Thinly bedded shales, slates, cherts, and limestones. Fauna includes brachiopods, trilobites, cephalopods, and lamellibranchs. [a]
		Conformity (?).	500+	(*c*) Thinly bedded black shales, slates, and limestones. Several coal beds. Lower Carboniferous flora. Brachiopod and coral fauna. [b]
Devonian (?).			2,000+	Calcareous sandstones and slates. No fossils found.

[a] The brachiopods, trilobites, and cephalopods were obtained at only two localities (4 AC 15 and 4 AC 17, which possibly do not belong in this formation.

[b] In one possible instance.

The preceding table shows that the rocks south and southeast of Cape Lisburne were divided by Collier into three supposed lower Carboniferous formations. The fossils of the upper and lower formations prove beyond doubt that they are of lower Carboniferous age. Collier considered that the three formations were in conformable sequence, and as the fossils of the "middle formation" were regarded as of rather indefinite character, the Carboniferous age of the entire sequence was not doubted. It should be pointed out that the structure in this district is very complex, overturned folds and thrust faults being numerous and all the less rigid beds being minutely crumpled. It should also be remembered that Collier, in addition to measuring stratigraphic sections and collecting fossils, obtained sections and samples from a large number of coal beds and carried topographic and geologic mapping along 100 miles of un-

[10] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, p. 16, 1906.

sheltered ocean coast, doing all this traveling in an open boat during a single month in which "there were not more than 10 calm days." It is consequently not surprising that the sequence as given above is not altogether correct, a reexamination of the fossils having shown that the fauna at some of the localities referred to the "middle formation" is Upper Triassic.[11] This conclusion makes it necessary to reconsider the evidence concerning the age of this formation and its stratigraphic and structural relations to the Lisburne limestone and to the lower coal-bearing formation. On reconsidering the evidence in full (see pp. 109–112) the writer concludes that the entire "middle formation" is Upper Triassic, its contacts with the lower Carboniferous rocks of the Lisburne limestone being thrust faults. The general sequence near Cape Lisburne is probably about the same as at Cape Thompson, where the section described by Kindle[12] may be represented as follows:

General section of Mesozoic and Paleozoic rocks near Cape Thompson

	Feet
Jurassic or Cretaceous (?): Soft black shale	500+
Upper Triassic: Chert, shale, and thin-bedded limestone	625
Carboniferous (?): Light-gray cherty limestone	2,000±
Lower Carboniferous:	
Light-gray limestone with abundant lower Carboniferous fossils, chiefly corals and brachiopods	3,000+
Shale and sandstone, with lower Carboniferous fossil plants	400

SHALE, CHERT, AND LIMESTONE NEAR CAPE LISBURNE

Historical review.—The Upper Triassic rocks near Cape Lisburne were first described by Collier[13] as the "middle formation" of the local Carboniferous section, and were assigned to the lower Carboniferous because of their apparent position beneath the Lisburne limestone and above the "lower formation," both of which contain lower Carboniferous fossils.

The same publication includes a short general discussion of the fauna of these beds by G. H. Girty,[14] with lists of the fossils that Collier collected. The fossils from the beds that are now regarded as Triassic were discussed briefly, with a statement that they are different from the characteristic lower Carboniferous faunas of the other formations and seem to include no diagnostic forms, and were assigned tentatively to the lower Carboniferous on the basis of an

[11] Kindle, E. M., The section at Cape Thompson, Alaska: Am. Jour. Sci., 4th ser., vol. 28, pp. 527–528, 1909.

[12] Idem, pp. 520–528.

[13] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 287, pp. 16, 18, 19–21, pl. 1, 1906.

[14] Idem, pp. 22–26.

assumption that the strata from which they were obtained are interbedded with the known Carboniferous rocks.

The presence of Upper Triassic rocks near Cape Lisburne was first pointed out by Kindle [15] on the basis of the following statement by Stanton:

> Among the collections obtained by Mr. Collier in the Cape Lisburne region some years ago there are several small lots consisting mainly of a form that seems to be identical with *Pseudomonotis subcircularis* and probably comes from about the same horizon as this Cape Thompson locality. These fossils were at that time identified as *Aviculopecten* and referred to the Carboniferous, chiefly because of the stratigraphic relations they were supposed to hold with well-characterized Carboniferous faunas.

Kindle added a brief statement indicating which of the collections previously regarded as Carboniferous were to be considered probably Triassic.

The Triassic rocks at Cape Lisburne were described briefly, on the basis of Collier's description, by Martin,[16] who pointed out that the entire "middle formation" of Collier is probably Triassic.

Stratigraphic description.—The Triassic rocks near Cape Lisburne, which have a thickness of over 1,000 feet and contain *Pseudomonotis subcircularis* (Gabb), constitute the "middle formation" of the Carboniferous as described by Collier. Neither base nor top of these beds has been recognized, all the observed contacts being faults. The next older rocks known in the vicinity are the lower Carboniferous (Mississippian) beds of the Lisburne limestone, and the next younger are the Corwin formation, of Cretaceous or Jurassic age. Collier's description [17] of the "middle formation" is as follows:

> The middle formation of the Carboniferous series has also been identified at three localities along the coast. It consists of thinly bedded black slates, shales, cherts, and cherty limestones and is distinguished from the lower formation, which it resembles in general appearance, by the absence of coal beds or fossil flora of any kind, and from the upper formation of the series, first by its lithologic character and second by its fauna, which consists principally of brachiopods and mollusks, while that of the upper consists principally of corals. In general the formation is harder than the coal-bearing formation, and for this reason the topography produced by it is more rugged. Like the coal-bearing formation it is rather intensely folded, and faulting has usually occurred along its contacts with the massive limestones which overlie it.

The "middle formation" has been recognized in three or four areas in the Lisburne region. The area that yielded most of the Triassic fossils (lots 4 AC 15, 4 AC 18, 4 AC 21, 4 AC 81, 4 AW 33,

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[15] Kindle, E. M., The section at Cape Thompson, Alaska: Am. Jour. Sci., 4th ser., vol. 28, pp. 527–528, 1909.

[16] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 703–704, 1916.

[17] Collier, A. J., op. cit., pp. 19–20.

4 AW 34) is a belt about 2 miles wide which extends southeastward from a point on the coast near Wevok, about 3 miles east of Cape Lisburne, between an area of supposed Cretaceous rocks on the northeast and an area of the Lisburne limestone on the southwest. The contact of the "middle formation" with the supposed Cretaceous rocks, as indicated in Figure 2, was regarded by Collier as probably an overthrust fault.

The relation between the "middle formation" and the Lisburne limestone is not so clear, it being stated that the Lisburne limestone

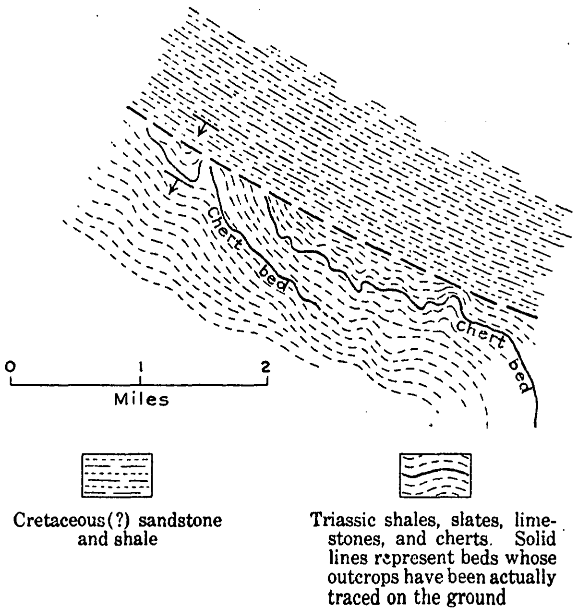

FIGURE 2.—Ground plan of outcrops adjoining the probable fault contact between the Triassic and Cretaceous (?) formations 3 miles east of Cape Lisburne. (After A. J. Collier)

seems to overlie the cherty rocks of the "middle formation" but that—

along the poorly exposed contact there is brecciation and other evidences of faulting. The slate and chert area here is marked by low hills and valleys, above which the massive limestone mountains rise abruptly to an elevation of about 1,000 feet. The base of this mountain extends in a nearly straight line, which suggests a fault escarpment. In this area the sinuous outcrops of the cherty beds (see fig. 2), which can be traced for considerable distances, indicate that the formation is intensely crumpled and probably closely folded.

In view of this suggestion of faulting, together with the testimony of the fossils to the effect that the apparently underlying beds are the younger, an overthrust fault may reasonably be assumed along the southwestern as well as the northeastern boundary of the cherty rocks of this area.

The same Triassic fauna has been collected about 3 miles north of Cape Lewis (4 AW 38), from chert beds 450 or 500 feet thick. These

cherts seem to be both overlain and underlain conformably by limestone. The underlying limestone contains Carboniferous fossils (4 AW 39), but no fossils were collected from the overlying beds.

Chert beds which are similar to those containing the Triassic fauna but from which no fossils have been obtained occur also about a mile south of Cape Lewis. Collier says of the "middle formation" of this locality: "It seems to rest conformably on the coal-bearing formation and to be overlain conformably by the massive limestone [Lisburne], as shown in Figure 3. Its thickness here is estimated at about 1,000 feet." The notes taken by Chester Washburne at this locality read:

In the sketch [fig. 3] the underlying limestone on the right is thin bedded, black, and in places somewhat sandy. It contains many brachiopods and corals, of which 4 AW 35 is a sample collection. This limestone is about 200 feet

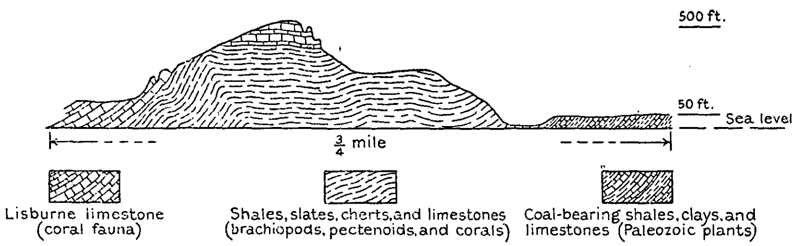

FIGURE 3.—Sketch showing stratigraphic relations of the Triassic and Carboniferous formations south of Cape Lewis. (After A. J. Collier)

thick. Overlying it is a thin-bedded varicolored chert, mostly black, about 250 feet thick and somewhat contorted. Overlying the chert, probably conformably, is another thin-bedded limestone, purer than the first and with an exposed thickness in the next hill north (Cape Dyer) of [several] thousand feet. The basal 500 feet of this limestone contains considerable interstratified nodular and broken chert and numerous fossils (4 AW 36). Above 500 feet from the base chert fragments are comparatively rare.

As the fossils in lots 4 AW 35 and 4 AW 36 are clearly Carboniferous, it is evident either that the cherty beds at this locality are not Triassic or that there is a fault between the cherty rocks and the apparently overlying limestone. The latter alternative is the more probable, for the basal contact of the upper limestone as represented in Figure 3 and more especially as drawn in the original field sketch is not parallel to the bedding of the underlying cherty beds and might be either an unconformity or a thrust fault.

The "middle formation" is also represented on the map as occurring at a locality 4 miles south of Cape Lisburne. No fossils have been collected at this locality, nor have the local relations been described.

Age and correlation.—The Triassic shale, chert, and limestone near Cape Lisburne have yielded the fossils listed in the following table.

The presence of *Pseudomonotis subcircularis* indicates a correlation with the *Pseudomonotis*-bearing beds at the tip of the Upper Triassic. No trace of the older Triassic faunas has been found near Cape Lisburne.

Fossils from Upper Triassic shale, chert, and limestone near Cape Lisburne[a]

	4 AC 15	4 AC 18	4 AC 21	4 AC 81	4 AW 33	4 AW 34	4 AW 38	4 AW 45	(?)
Sponge?	a								
Pararca?					a	a			a
Nucula?		a			a	a	a		
Pseudomonotis subcircularis (Gabb)	b	b	b	b	b	b	b	b	b

[a] a, Identified by George H. Girty; b, identified by T. W. Stanton.

4 AC 15. 1½ miles southeast of Wevok. Chert, cherty limestone, and shale. A. J. Collier, 1904.

4 AC 18. 3½ miles southeast of Wevok. A. J. Collier, 1904.

4 AC 21. 3 miles east-southeast of Wevok. A. J. Collier, 1904.

4 AC 81. 4 miles southeast of Wevok. A. J. Collier, 1904.

4 AW 33. About 2 to 3½ miles southeast of Wevok. Chert. C. W. Washburne, 1904.

4 AW 34. About half a mile southeast of camp near Wevok. Chert. C. W. Washburne, 1904.

4 AW 38. 3½ miles north of Cape Lewis. Chert 450 or 500 feet thick, which is conformably underlain and overlain by fossiliferous limestone. From the underlying limestone the fossils of lot 4 AW 39 were obtained. C. W. Washburne, 1904.

4 AW 45. Cobblestone on beach at south side of Point Hope. C. W. Washburne, 1904.

(?) Southeast of Wevok. Collier and Washburne, 1904.

CHERT AND LIMESTONE NEAR CAPE THOMPSON

Historical review.—The presence of Upper Triassic rocks near Cape Thompson was first indicated by Hyatt[18] in the following statement: "A slab from Cape Thompson, Arctic coast, has numerous specimens of *Halobia*, or *Daonella*, and is probably Triassic."

Cape Thompson was not actually visited by Collier, but he made a sketch showing the geologic section exposed in the cliffs as seen from the deck of the steamship *Corwin* at a distance of about 3 miles.[19] This sketch is shown in Figure 4. The arch in the center, which is called "Agate Rock," is shown in greater detail in a photograph[20]

[18] Hyatt, Alpheus, Report on the Mesozoic fossils: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 907, 1896.

[19] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, p. 21, fig. 7, 1906.

[20] Idem, pl. 4, *A*.

which Collier obtained from Doctor Call, surgeon of the United States revenue cutter *Thetis*.

The fossils from Cape Thompson that were identified by Hyatt as probably Triassic were discussed briefly by G. H. Girty,[21] who stated that they resemble and occur in a matrix similar to that containing the doubtful fossils from Cape Lisburne that are now regarded (see p. 108) as Triassic.

The occurrence of Upper Triassic rocks near Cape Thompson was described by Kindle,[22] who gave a stratigraphic section showing the position of the fossiliferous Triassic beds and discussed their relation to the underlying and overlying rocks in some detail.

The Triassic rocks near Cape Thompson have been briefly described by Martin.[23]

Stratigraphic description.—The Triassic rocks near Cape Thompson consist of chert, argillite, and thin-bedded limestone aggregating 625 feet in thickness. They rest with apparent conformity on unfossiliferous limestone which overlies a Mississippian (lower Carboniferous) limestone and which is supposed to be of Carboniferous age. They are overlain with apparent conformity by shale that is possibly Jurassic or Cretaceous. *Pseudomonotis subcircularis* (Gabb) has been obtained near the top of the strata referred to the Triassic.

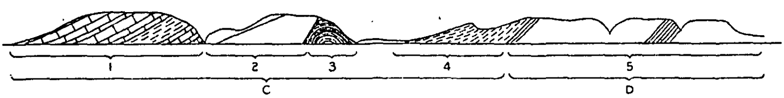

FIGURE 4.—Sketch of the section exposed in the cliffs at Cape Thompson. (After A. J. Collier)

The Triassic rocks, according to Kindle, are exposed in a belt 1½ to 2 miles wide, bounded on both sides by Carboniferous limestone. The Triassic rocks lie in a syncline whose axis trends north of northwest and reaches the coast about 2 miles southeast of the northwesterly outcrops near Cape Thompson. The Triassic and overlying beds are apparently included in No. 4 in the accompanying sketch by Collier.[24] (See fig. 4.) It should be noted, however, that, according to Kindle, the structure is not altogether correctly represented in this sketch. The character and occurrence of the Triassic and associated rocks near Cape Thompson were described by Kindle [25] as follows:

[21] Collier, A. J., op. cit., p. 25.

[22] Kindle, E. M., The section at Cape Thompson, Alaska: Am. Jour. Sci., 4th ser., vol. 28, pp. 521–522, 526–528, 1909.

[23] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 703–704, 1916.

[24] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, p. 21, 1906.

[25] Kindle, E. M., op. cit., 526.

The higher beds of the Cape Thompson section are brought in contact with the beds already described in the midst of a zone of rather local but complicated folding and possibly of faulting, which renders it impossible to give even an approximate estimate of their thickness as seen from the top of the southeastern portion of the Cape Thompson cliffs; but between the second and the fourth deep ravines separating the high ridges just southeast of the cape along the coast the exposures are continuous for 2 miles, exposing a section of northerly dipping beds in which the dip decreases from 35° to 0 near the middle of the synclinal. We find in the series of cliffs which face the sea to the southeast of the second ravine below Cape Thompson a section which passes without structural complications from the fossiliferous Carboniferous limestones to the top of the highest beds exposed in this vicinity. This section is as follows:

Section 15, 2 miles southeast of Cape Thompson

	Feet
e. Soft black shales	500+
d. Dark cherts and thin-bedded cherty limestones with some greenish bands	25
c. Argillites with bands of black, green, and dull red cherts	600
b. Light-gray limestone weathering buff, with some bands of dark chert. Apparently barren of fossils	2, 000+
a. Light-gray limestone similar to the above but with less chert and containing numerous fossils, in which corals are conspicuous	3, 000+

The lowest member (a) of this section contains a characteristic lower Carboniferous fauna. No fossils were obtained from the next higher member (b), which consequently may be either Carboniferous or Triassic. According to Kindle,[26] however,

The close physical resemblance of the second division (b) of the limestone series to the lower leaves little doubt that it is also of Carboniferous age. It may represent the upper Carboniferous, which has not been recognized anywhere on the northwestern coast of Alaska, though known on the Yukon and in southeastern Alaska.

The contact between the Triassic and the Carboniferous rocks, according to Kindle, is probably at the base of bed c, and the highest black shale (e) was believed to be possibly the equivalent of the Cretaceous or Jurassic Corwin formation. (See p. 457.) Kindle described the supposed Triassic members of this section as follows:

The lithologic change at the top of this limestone series is abrupt. The beds included in c and d are essentially similar and represent the same formation, although there is less of the calcareous element in the lower beds. Fossils were found, however, only in the upper beds marked d in the section. They occur in great abundance in certain strata in this portion of the section. About 7 feet near the top are composed almost exclusively of shells which have been largely altered to chert.

Age and correlation.—The only fossils that have been obtained from the Triassic rocks near Cape Thompson are the collection de-

[26] Kindle, E. M., op. cit., p. 527.

scribed by Hyatt and the collection obtained by Kindle, described on pages 113–114 and listed below. Concerning the fossils collected by Kindle (lot 15d) Stanton[27] said:

This collection consists of limestone fragments with numerous specimens of aviculoid shells referable to *Pseudomonotis subcircularis* (Gabb) or to a closely related species. No other recognizable species are associated with it. This species occurs in an Upper Triassic horizon in California, and it has been accepted as sufficient evidence for the Triassic age of rocks containing it at Cold Bay and in the Copper River region of Alaska. In my opinion the horizon which yielded it at Cape Thompson is also Upper Triassic.

The localities are as follows:

15d. Mouth of creek 2 miles southeast of Cape Thompson. Uppermost 7 feet of bed d in section on page 114. E. M. Kindle, 1908. *Pseudomonotis* cf. *P. subcircularis* (Gabb).

(—). Near Cape Thompson. Exact bed and collector not known. *Halobia* or *Daonella*. (Identified by Alpheus Hyatt.)

ST. LAWRENCE ISLAND

TRIASSIC (?) FLOAT

It is possible that Upper Triassic rocks are present on St. Lawrence Island, where Collier[28] found a boulder of uncertain derivation which he described as follows:

On St. Lawrence Island Carboniferous rocks of the formation immediately below the Lisburne are probably represented, since drift material containing fossils of this horizon has been obtained by the writer on the island at some distance from the sea, though the rocks in place have not yet been located.

The fossils in this boulder were referred by Girty[29] to the Carboniferous on account of their identity with the supposed Carboniferous (Triassic) fossils of the "middle formation" at Cape Lisburne, described on pages 109–112, it being stated that

* * * and a specimen from St. Lawrence Island (4 AC 53), though rather scanty evidence, as they show what apparently is the same species in the same sort of matrix, can with a good degree of probability be correlated with the beds about Cape Lisburne.

If these fossils are identical with the supposed "*Aviculopecten*" from the "middle formation" near Cape Lisburne, described on pages 109–112, they are obviously of Triassic age. This does not, however, prove that Triassic rocks crop out on this island, for there is a possibility that the fossiliferous boulder was transported by ice from the mainland. It may have been derived from outcrops on the shore near Cape Lisburne.

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[27] Stanton, T. W., cited by Kindle, E. M., op. cit., p. 527.

[28] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, p. 26, 1906.

[29] Idem, pp. 23, 25.

4 AC 53. 15 miles southeast of Cape Chibukak, St. Lawrence Island. Drift pebble. *Aviculopecten* sp. (same as at 4 AC 18)=*Pseudomonotis subcircularis* (Gabb)? A. J. Collier, 1904.

SEWARD PENINSULA

MIDDLE TRIASSIC ROCKS OF BROOKS MOUNTAIN

The presence of Triassic rocks on Seward Peninsula is indicated by a small collection of fossils of Middle Triassic age, which are reported by Kindle[30] to have been collected from black slate, between 1,000 and 2,000 feet above sea level, on the southeast slope of Brooks Mountain, in the western part of Seward Peninsula. The occurrence and age of these fossils have been discussed by Martin.[31]

As the field occurrence of these fossils has never been studied by a geologist it is impossible to affirm positively just what beds contain them. They were probably, however, derived from the area of slate that forms a large part of Brooks Mountain. This slate was described by Collier[32] as probably part of the Kuzitrin "series" and as probably unconformably underlying the supposed Ordovician beds of the Port Clarence limestone. In a later account by Collier[33] they were described as "slates in the York region" and were mapped as "chiefly dark phyllites and slates" of "undetermined Paleozoic" age. They were described by Knopf[34] as "slates near York" and were considered as underlying the Port Clarence limestone conformably. It was pointed out by Kindle[35] that the slates of the Brooks Mountain area "have been correlated without any conclusive evidence of their identity" with the slates of the main area west of the York Mountains. Kindle did not state any conclusion regarding the relation of these slates to the Port Clarence limestone, but showed that the Port Clarence includes rocks "ranging in age from Upper Cambrian to Devonian or Carboniferous" and that "the determination of the thickness and relationships of the several terranes * * * must await the completion of much detailed work on the stratigraphy and faunas of the region."

The geology of Brooks Mountain has been studied by Steidtmann and Cathcart, who were unable to find any rocks that they regarded as of Triassic age. They described the rocks on Brooks Mountain as follows[36]:

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[30] Kindle, E. M., The faunal succession in the Port Clarence limestone, Alaska: Am. Jour. Sci., 4th ser., vol. 32, p. 339, 1911.

[31] Martin, G. C., Triassic rocks of Alaska: Geol. Soc. America Bull., vol. 27, pp. 690, 704–705, 1916.

[32] Collier, A. J., A reconnaissance of the northwestern portion of Seward Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 2, pp. 17, 19, 21, pl. 3, 1902.

[33] Collier, A. J., Geography and geology, in the gold placers of parts of Seward Peninsula, Alaska: U. S. Geol. Survey Bull. 328, pp. 79–80, pl. 11, 1908.

[34] Knopf, Adolph, Geology of the Seward Peninsula tin deposits, Alaska: U. S. Geol. Survey Bull. 358, pp. 10–12, 13, 1908.

[35] Kindle, E. M., op. cit., p. 339.

[36] Steidtmann, Edward, and Cathcart, S. H., Geology of the York tin deposits: U. S. Geol. Survey Bull. 733, p. 83, 1922.

The rocks at Brooks Mountain include an unknown thickness of black slate overlain by at least 1,000 feet of limestone. The contact between the slate and limestone is not exposed, hence it is not certain whether the slate was eroded before the limestone was laid down upon it. The lower 100 feet of the limestone consists of black slaty layers a fraction of an inch in thickness, interbedded with thin layers of gray fine-grained limestone. From this fact it would appear that there is a gradation from slate to limestone. The slates, however, are more intensely folded than the basal limestone beds. In position and character they are like the slates of other parts of the York region. Outside of the Brooks Mountain area the evidence is strong that the slates lie unconformably below the limestones, hence it is probable that they bear the same relation here.

The limestone was assigned by Steidtmann and Cathcart to the Ordovician and Silurian and the slate to the Cambrian or pre-Cambrian. A statement by Kirk[37] on the fossils is quoted, in which the presence of Carboniferous corals from the north side of Brooks Mountain is mentioned.

The failure of any of the geologists, especially of Steidtmann and Cathcart, to find Triassic fossils on Brooks Mountain casts serious doubt on the supposed occurrence of Triassic rocks at that locality. It is possible that the fossils given to Kindle were brought from some other region, but the writer does not believe that this was done. It is entirely possible, in the writer's opinion, that unrecognized masses of Triassic rocks may be structurally included in the early Paleozoic limestone or that the slate which apparently underlies the limestone may be Triassic slate on which the limestone has been overthrust.

The following statement regarding the Triassic fossils that are supposed to have come from Brooks Mountain was made by T. W. Stanton:

5654. Southeast slope of Brooks Mountain, between 1,000 and 2,000 feet above sea level. From black slates. Collected by Peter Esch, of Nome, 1908:

Daonella cf. D. lommeli Wissmann.

Ceratites (Gymnotoceras) sp.

These are characteristic Triassic fossils and probably came from the Middle Triassic. The collection is interesting from the fact that it affords the first evidence of the existence of Triassic rocks in that part of Alaska.

It should be noted also that these are the only Middle Triassic fossils known from Alaska.

GENERAL CHARACTER AND CORRELATION

MIDDLE TRIASSIC

The only known Middle Triassic rocks in Alaska are the slates of Brooks Mountain, Seward Peninsula. It has already been shown that these rocks occur in a region where no other Triassic rocks are

[37] Steidtmann, Edward, and Cathcart, S. H., op. cit., pp. 27–28.

known, and that Middle Triassic rocks that can be correlated with them do not occur in other Alaskan regions.

The fossils in this locality include a species of *Daonella* that is closely related to though probably not identical with the species from Nevada and California which has been referred to *Daonella lommeli* Wissman, and an undetermined species of *Ceratites* (*Gymnotoceras*). *Daonella lommeli* Wissman is a European species which is considered characteristic of beds that are generally referred to the Ladinic and, according to most writers, are regarded as representing the uppermost division of the Muschelkalk, or Middle Triassic, although they are sometimes regarded as constituting the lowest division of the Upper Triassic. The fossils from Nevada that have sometimes been considered identical with *Daonella lommeli* are regarded by J. P. Smith[38] as constituting a distinct species, *Daonella dubia* Gabb, and as belonging near the middle of the Middle Triassic. *Gymnotoceras* is an ammonite which is supposed to be highly characteristic of the Arctic type of Middle Triassic faunas. All known American species of *Gymnotoceras* are characteristic of the *Daonella dubia* zone of the Middle Triassic of Nevada. The Alaskan fossils are presumably to be regarded as belonging in approximately the same position.

The same horizon is probably represented by part of the Nicola series of the Interior Plateau region of British Columbia. The Nicola series[39] is a thick succession of volcanic rocks with some interbedded limestone and argillite containing *Pentacrinus asteriscus*, *Terebratula humboldtensis*, *Spiriferina* or *Cyrtina*, *Myacites* cf. *M. humboldtensis*, *Daonella* cf. *D. lommeli*, *Trigonodus*, *Cardita*, and *Panopea* cf. *remondi*.[40] The Nicola series has been supposed to contain *Pseudomonotis subcircularis*, but this fossil does not occur in association with the others, having been obtained from an outlying area of argillite resting on volcanic beds that were correlated with those of the Nicola series.[41]

It should be noted that *Daonella lommeli* has been reported from many other localities in British Columbia. As in most of these reports more or less doubt has been expressed concerning the identification; as the Canadian fossil doubtfully referred to this species

[38] Smith, J. P., The Middle Triassic marine invertebrate faunas of North America: U. S. Geol. Survey Prof. Paper 83, pp. 143–144, 1914.

[39] Dawson, G. M., Report on the area of the Kamloops map-sheet, British Columbia: Canada Geol. Survey Ann. Rept., new ser., vol. 7, pp. 49B–62B, 112B–146B, 1896.

[40] Idem, pp. 50B–51B. (The crinoid and brachiopods were identified by Whiteaves, the pelecypods by Hyatt.)

[41] Dawson, G. M., Preliminary report on the physical and geological features of the southern portion of the interior of British Columbia: Canada Geol. Survey Rept. Progress for 1877–78, pp. 66B–67B.

has never been described or figured; and as in nearly all the reports the fossil has been listed as occurring in close association with characteristic Upper Triassic forms, the writer believes that the species may have been incorrectly identified and that it is probably an Upper Triassic species of *Halobia*. There is as yet no proof that Middle Triassic rocks are present in British Columbia, except in the Kamloops district. (See p. 126.)

UPPER TRIASSIC

General distribution.—Upper Triassic rocks are widely distributed throughout those parts of Alaska occupied by the Pacific, Rocky, and Arctic Mountain systems, which are the three major mountain regions of the Territory. The Triassic deposits in each of these regions constitute a section which, in its general stratigraphic and faunal character, is more or less typical of that entire region but which differs in greater or less degree from the sections in the other regions. These resemblances and differences possibly mean that the present major mountain areas occupy the sites of Triassic basins of deposition. The most complete local representation of these rocks is in the Chitina Valley, which must now and probably will always be regarded as containing the typical and standard section of the Upper Triassic rocks of Alaska and more especially of the Pacific Mountain region. The Chitina Valley section is typical in all its more essential features, both stratigraphic and faunal, of the Upper Triassic deposits of southern Alaska, although representatives of several horizons known in other Alaskan districts have not yet been recognized here. The Upper Triassic rocks of the region south of the Alaska Range are underlain in most places by volcanic beds that include the Nikolai greenstone of the Chitina Valley and the similar and probably corresponding lava or tuff and lava of other districts. Volcanic rocks are not present in this stratigraphic position north of the Alaska Range, where the Upper Triassic rocks rest directly on late Paleozoic limestone.

Dawsonites zone.—The occurrence in southeastern Alaska of an Upper Triassic limestone that is probably older than any Upper Triassic beds known elsewhere in Alaska is indicated by the presence, on the shores of Hamilton Bay, Kupreanof Island, of float containing fossils related to *Spiriferina borealis* Whiteaves and *Dawsonites canadense* Whiteaves. Neither of these species has been found elsewhere in Alaska or at any American localities except in the Triassic rocks of Liard River, in the eastern foothills of the Rocky Mountains of British Columbia.

The Triassic rocks of Liard River, according to McConnell,[42] "consist of dark shales, usually rather coarsely laminated, and passing into calcareous shales interstratified with sandstones and shaly and massive limestones." The fossils, which have been described by Whiteaves,[43] include 11 species, among which are *Spiriferina borealis* Whiteaves and *Dawsonites canadense* Whiteaves, which have been doubtfully identified from Hamilton Bay. Mojsisovics[44] has pointed out that some of these fossils are indicative of Karnic age. Three of the Liard River species (*Dawsonites canadense*, *Nathorstites McConnelli*, and *Nathorstites lenticularis*), one of which occurs at Hamilton Bay, have been found, according to Böhm,[45] in the Upper Triassic rocks of Bear Island, between Norway and Spitzbergen. The Triassic rocks of Bear Island, are generally regarded as of Karnic (possibly Lower Karnic) age, and an assignment of the beds on Liard River to the same position has been made by Frech[46] on the basis of the presence of the above-mentioned species, which are common to the two regions.

The Hamilton Bay fauna may also be tentatively correlated with that from Bear Island and referred to the Karnic. This fauna possibly represents a boreal facies of the Karnic which has not been recognized farther south in North America.

Zone of Halobia cf. H. superba.—The Chitistone limestone, which is the basal formation of the Upper Triassic section in Chitina Valley, is represented in other parts of the Pacific Mountain system by limestones which, although thinner, are similar to the Chitistone limestone in their general lithologic character, in their stratigraphic position between underlying volcanic rocks and overlying shale or chert with *Pseudomonotis*, and in the general character of their fauna. The limestones which should be correlated with the Chitistone limestone include those of the upper Susitna Valley, of Herring Bay on Admiralty Island, and part of the Triassic limestone of Hamilton Bay on Kupreanof Island.

The fauna of these limestones includes unidentified species of *Tropites*, *Juvavites?*, and *Arcestes*, a species of *Halobia* closely related to *Halobia superba* Mojsisovics, and many other fossils of lesser significance. These fossils show that the fauna is certainly Upper Triassic and that it probably belongs in the middle or Karnic

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[42] McConnell, R. G., Report on an exploration in the Yukon and Mackenzie basins, Northwest Territory: Canada Geol. Survey Ann. Rept., new ser., vol. 4, pp. 19D, 49D, 1890.

[43] Whiteaves, J. F., On some fossils from the Triassic rocks of British Columbia: Contr. Canadian Paleontology, vol. 1, pt. 2, No. 3, pp. 127–149, pls. 17, 18, 1889.

[44] Mojsisovics, Edmund von, Beiträge zur Kenntniss der obertriadischen Cephalopoden-Faunen des Himalaya: K. Akad. Wissenschaften Wien Denkschr., Band 63, p. 697, 1896.

[45] Böhm, Johannes, Ueber die obertriadische Fauna der Bäreninsel: K. svenska Vetenskaps-Akad. Handlingar, Bandet 37, No. 3, pp. 56–58, 61–64, 73–76, 1903.

[46] Frech, Fritz, Die zirkumpacifische Trias: Lethaea geognostica, Teil 2, Das Mesozoicum, Band 1, Trias, pp. 488–491, 508, 1908.

Tentative correlation of the Triassic rocks in various parts of Alaska

Age	Nizina Valley	Kotsina and Kuskulana valleys	White River	Cooper Pass	Upper Susitna Valley	East Fork of Chulitna River	West Fork of Chulitna River	Kenai Peninsula	West coast of Cook Inlet
Upper Triassic. Upper Noric.	McCarthy formation (shale and thin limestone with *Pseudomonotis subcircularis*; much chert in lower 1,000 feet). 1,500 to 2,000 feet.	Kuskulana formation. (Black shale with thin limestone). Contains *Pseudomonotis subcircularis*. 2,000 (?) feet.	Lava, tuff, and breccia with *Pseudomonotis*. Shale with *Pseudomonotis*. Underlain unconformably by Permian (?) limestone.	Thin-bedded limestone with *Pseudomonotis subcircularis*. Thickness and relations not known.	Slate, tuff, arkose, and calcareous beds with *Pseudomonotis subcircularis*. Many hundred feet.	Thin-bedded limestone and shale with *Pseudomonotis subcircularis* and *Heterastridium*.		Limestone with *Pseudomonotis subcircularis* near top and *Halobia* below. 1,000+ feet.	Kamishak chert. Calcareous shale and some chert. Contains *Pseudomonotis subcircularis*. 1,000 (?) feet.
Upper Triassic. Upper Noric / Lower Noric.	—Conformity (?)—	—Unconformity (?)—						Contorted chert. Thickness unknown.	Kamishak chert. Massive chert with no fossils. 1,000 (?) feet.
Upper Triassic. Lower Noric.									Limestone with *Halobia*. Thickness and relations not known.
Upper Triassic. Karnic or Noric.	Nizina limestone (thin-bedded limestone). No fossils. 1,000 to 1,200 feet. —Conformity—	Kuskulana formation. Thin-bedded limestone with some shale. Fauna similar to that of Chitistone limestone. 500 to 3,000 feet.					Tuff, limestone, shale, and lava with *Cassianella* (underlain unconformably by greenstone).		
Upper Triassic. Karnic.	Chitistone limestone. (massive bluish-gray limestone). Contains *Halobia* cf. *H. superba*, *Tropites*, *Juvavites*, *Arcestes*, etc. 1,800 to 2,000 feet.	Chitistone limestone (massive limestone). 300 to 1,200 (?) feet.			Limestone with *Halobia* cf. *H. superba*, *Tropites*, etc. A few hundred feet.				
Upper Triassic. Karnic.	—Conformity (?)—	—Conformity (?)—							
Middle Triassic.									
Permian or Triassic.	Nikolai greenstone (basalt lava). 4,000 to 5,000 feet. Base not exposed.	Nikolai greenstone (basalt lava). 6,500(?) feet. Underlain by Carboniferous beds.			Basic lava and tuff. 3,500 feet. Probably underlain by Carboniferous (?) limestone.			Ellipsoidal lava. 3,000 feet. Underlain by slate and graywacke of unknown age.	Greenstone. Thickness and relations not known. Probably underlain by slate.

Age	Iliamna Lake	Alaska Peninsula	Kodiak Island	Gravina Island	Screen Islands	Keku Strait	Herring Bay, Admiralty Island	Juneau district	Yukon River near Nation River
Upper Triassic. Upper Noric.		Limestone and shale with *Pseudomonotis subcircularis*. 700+ feet.				Basaltic and andesitic lava, breccia, and tuff interbedded with cherty limestone with *Pseudomonotis subcircularis*. Basal conglomerate.	Limestone with *Pseudomonotis subcircularis*.		Calcareous shale and shaly limestone with *Pseudomonotis subcircularis*.
Upper Triassic. Upper Noric / Lower Noric.		Contorted chert with no fossils. Thickness not known.	Contorted chert with no fossils. Thickness not known.			—Unconformity (?)—	Chert and shale with no fossils. Position doubtful.		—Conformity (?)—
Upper Triassic. Lower Noric.	Limestone with corals. Thickness several hundred feet.			Shales with *Halobia* cf. *H. superba*. Limestone with corals. (Position and relations uncertain). Probably underlain by Devonian limestone.					
Upper Triassic. Karnic or Noric.					Limestone of unknown position (underlain by Permian limestone).				
Upper Triassic. Karnic.						Conglomerate limestone and sandstone with *Halobia* cf. *H. superba*, etc. Relation to *Dawsonites*-bearing beds not known.	Limestone with *Halobia* cf. *H. superba*, *Juvavites*, *Arcestes*, etc. 273 feet. Basal contact not seen.	Gastineau volcanic group (lower member). Slate containing *Halobia* cf. *H. superba* interbedded with andesitic lava and tuff.	Limestone and shale with *Halobia* cf. *H. superba* and *Clionitis* (?). Basal limestone bed with many brachiopods, nautiloids, and *Trachyceras* cf. *T. leconti*. 300+ feet. Underlain by Permian (?) limestone.
Upper Triassic. Karnic.						Limestone float with *Spiriferina borealis* (?) and *Dawsonites canadense* (?).			
Middle Triassic.									
Permian or Triassic.	Greenstone (?)	Greenstone.	Ellipsoidal lava. Thickness unknown. Probably underlain by slate and graywacke.			Ellipsoidal lava. Relations to *Dawsonites*-bearing beds not known. Underlain by Permian (?) limestone.			

Age	Kantishna district	Firth River	Canning River	Noatak Valley	Cape Lisburne	Cape Thompson	St. Lawrence Island	Brooks Mountain, Seward Peninsula
Upper Triassic. Upper Noric.		Limestone with *Pseudomonotis subcircularis*. Thickness and relations unknown.	Float with *Pseudomonotis subcircularis*. Derivation uncertain.	Float of cherty limestone with *Pseudomonotis subcircularis*. Derivation not known.	Shale, chert, and limestone with *Pseudomonotis subcircularis*. 1,000+ feet. Probably underlain by Carboniferous limestone.	Chert and limestone with *Pseudomonotis subcircularis*. 625 feet. Underlain by Carboniferous (?) limestone.	Float with *Pseudomonotis subcircularis*. Derivation uncertain.	
Upper Triassic. Upper Noric / Lower Noric.								
Upper Triassic. Lower Noric.								
Upper Triassic. Karnic or Noric.	Limestone of unknown position (contains corals).							
Upper Triassic. Karnic.		Flaggy limestone with *Halobia* cf. *superba*. Thickness not known. Underlain by Permian (?) limestone.	Shublik formation. Black shale with *Halobia* cf. *H. superba*; Limestone and some shale with *Halobia* cf. *H. superba*, brachiopods as at Nation River, *Gervillia*, *Megalodon* (?), and *Clionites* (?) Calcareous sandstone without characteristic fossils.					
Upper Triassic. Karnic.								
Middle Triassic.								Slate with *Ceratites* (*Gymnotoceras*) and *Daonella*. Thickness and relations not known.
Permian or Triassic.			Permian (?) limestone.					

stage of the Upper Triassic. Although most of the identified genera of brachiopods and pelecypods have a long range, yet both the character of many of the individual forms and the general aspect of the assemblage are unmistakably Triassic. The ammonites all belong to highly characteristic Upper Triassic genera and point strongly toward a horizon in the Karnic, as does also the pelecypod identified as *Halobia* cf. *H. superba* Mojsisovics. The latter, according to Stanton, is identical with the species known by that name in the Triassic rocks of California and is very closely related to *Halobia superba* of the Triassic rocks of Europe, even though it may not be the same. The Chitistone limestone may be regarded as certainly the equivalent of at least part of the Hosselkus limestone of California and as probably representing in general the lower part of the Hosselkus limestone. The Chitistone fauna belongs to the Mediterranean type of Triassic faunas and is believed to be indicative of warm-water conditions.

On Yukon River and in the eastern part of the Arctic Mountains (Firth and Canning Valleys) are limestones which seem to correspond in general position to the Chitistone limestone. The fauna of these limestones is connected with that of the Chitistone limestone by the presence of *Halobia* cf. *H. superba*, although it differs from it in the absence of the characteristic ammonite genera *Tropites*, *Juvavites*, and *Arcestes*, of the corals, and of such pelecypods as *Myophoria* and *Pleuromya*. It differs also in the abundance of the brachiopods and in the presence of *Clionites* and several other genera that have not been found in the Chitistone limestone. This fauna may represent the boreal facies of the Karnic, which is elsewhere not well developed in America. The writer regards these beds as probably being approximately synchronous with the Chitistone limestone but as having been deposited in a different basin.

It is highly probable that the equivalent of the Chitistone limestone is present in the Queen Charlotte Islands, British Columbia, where, according to Dawson,[47] a massive limestone at least 400 feet thick rests on volcanic rocks and is overlain by thin-bedded limestone and flaggy calcareous argillite containing *Pseudomonotis subcircularis*. The similarity of this section to that of the Chitina Valley is striking and suggestive. It is not possible, however, to establish this correlation definitely on paleontologic evidence, for the published lists of fossils[48] unfortunately do not indicate which of the species described by Whiteaves[49] were obtained from the massive limestone. A suggestion that these fossils include Karnic forms

[47] Dawson, G. M., Report on the Queen Charlotte Islands: Canada Geol. Survey Rept. Progress for 1878–79, pp. 48B, 55B, 61B–62B, 63B, 1880.

[48] Idem; pp. 49B, 53B.

[49] Whiteaves, J. F., On some fossils from the Triassic rocks of British Columbia: Contr. Canadian Paleontology, vol. 1, pt. 2, No. 3, pp. 133–134, 141–142, 148–149, 1889.

has been made by Mojsisovics,[50] who said: "The same conclusion [of Karnic age] holds for *Aulacoceras carlottense*, since the genus *Aulacoceras* until now has been known only in the Karnic. The fragment of a coil figured as *Acrochordiceras? carlottense* may belong to a *Juvavites*."

The same horizon is possibly present at the north end of Vancouver Island, where, according to Dawson,[51] the section is very similar to that in the Queen Charlotte Islands and includes a massive limestone, possibly 1,000 feet thick, underlain by volcanic rocks and overlain by "flaggy limestones interbedded with calcareous argillites, black flinty argillites, and felsites." This limestone and also the supposedly equivalent limestone of the Queen Charlotte Islands is part of the thick and heterogeneous aggregate of rocks that has been described as the Vancouver series.

Coral-reef horizon.—An Upper Triassic limestone occurring on Iliamna Lake has yielded a fauna composed chiefly of corals, which has not been recognized with certainty elsewhere in Alaska and which, according to J. P. Smith,[52] is of Lower Noric age and is to be correlated with the coral-reef zone in the upper part of the Hosselkus limestone of California and in the Blue Mountains of Oregon and with the Zlambach fauna of the Alps. The position of this limestone in the Chitina Valley section is above the *Halobia* zone of the Chitistone limestone and below the *Pseudomonotis* zone of the McCarthy formation. It may be represented by the thin-bedded Nizina limestone or by beds that have been cut out by an unconformity at the base of the McCarthy formation.

This limestone may be present also on the west coast of Cook Inlet and on Gravina Island, in southeastern Alaska, but at neither of these localities has it been recognized with certainty.

The Lower Noric coral-reef horizon is possibly represented in British Columbia by the Sutton limestone[53] of Cowichan Lake, Vancouver Island. The fauna of the Sutton limestone has been described by Clapp and Shimer,[54] who referred it to the lower part of the Lower Jurassic on the ground that its species are more primitive than certain species from the Middle and Upper Jurassic of England and India, and are less primitive than certain species

[50] Mojsisovics, Edmund von, Beiträge zur Kenntniss der obertriadischen Cephalopoden-Faunen des Himalaya: K. Akad. Wiss. Wien Denkschr., Band 63, p. 697, 1896.

[51] Dawson, G. M., Report on a geological examination of the northern part of Vancouver Island and adjacent coasts: Canada Geol. Survey Ann. Rept., new ser., vol. 2, pp. 9B, 60B, 76B, 89B, 91B, 1886.

[52] Smith, J. P., The occurrence of coral reefs in the Triassic of North America: Am. Jour. Sci., 4th ser., vol. 33, pp. 92–96, 1912.

[53] Clapp, C. H., Southern Vancouver Island: Canada Geol. Survey Mem. 13 (1121), pp. 36, 61–69, 1912.

[54] Clapp, C. H., and Shimer, H. W., The Sutton Jurassic of the Vancouver group, Vancouver Island: Boston Soc. Nat. Hist. Proc., vol. 34, No. 12, pp. 425–438, pls. 40–42. 1911.

from the Rhaetic of Europe, and that it does not contain *Daonella lommeli*, *Halobia superba*, or *Pseudomonotis subcircularis*. They regarded it as representing a Eurasian type of Liassic fauna which is rather closely related to certain unspecified Liassic faunas of Europe and India.

The writer believes that the reasons stated for the reference of this fauna to the Lower Jurassic are, to say the least, by no means conclusive. The absence of *Daonella lommeli*, *Halobia superba*, and *Pseudomonotis subcircularis* does not make its assignment to the Triassic impossible or even improbable. On the other hand, the fact that all the five recognized genera occur abundantly in the Triassic, while two of them (*Choristoceras* and *Myophoria*) are highly characteristic of the Triassic, being authentically known, so far as the writer is aware, only in rocks of that system, makes it appear highly probable that this fauna is of Triassic age. The superficial resemblance of the corals, moreover, to those of the Lower Noric reefs of California, Oregon, Alaska, and the Alps suggests that the Sutton fauna may also be of Lower Noric age. In this connection it should be pointed out that the only recognized ammonoid genus, *Choristoceras*, in the Sutton fauna occurs also in association with the Zlambach corals of the Alps.

Chert horizon.—The chert that forms the lower part of the McCarthy formation of the Chitina Valley is apparently the equivalent of the more massive lower part of the Kamishak chert of the west coast of Cook Inlet and of the chert that occurs in a corresponding stratigraphic position beneath the *Pseudomonotis* zone of the Alaska Peninsula. The contorted chert of Kenai Peninsula, of Kodiak Island, and of Herring Bay on Admiralty Island is probably also to be assigned to the same position, though on more slender evidence. The occurrence of these cherts below the *Pseudomonotis* zone and above the *Halobia* zone in the Chitina Valley indicates their general position, but as they contain no fossils they can not be assigned to a definite horizon or be correlated with any rocks of other regions.

Zone of Pseudomonotis subcircularis.—The highest Upper Triassic rocks known in Alaska are the Upper Noric *Pseudomonotis*-bearing beds, which are widely distributed throughout the three major mountain regions. This horizon is represented in the Pacific Mountain belt by the McCarthy formation of the Chitina Valley and by strata carrying a similar fauna at the head of White River, at Cooper Pass, in the upper Susitna Valley, on both shores of Cook Inlet, on the Alaska Peninsula, and on Kupreanof Island in southeastern Alaska. In the Rocky Mountain area *Pseudomonotis*-bearing beds form the upper part of the Triassic section near Nation

River. Rocks belonging at the same horizon occur at many places throughout the Arctic Mountains, being known on Firth, Canning, and Noatak rivers and at Cape Lisburne and Cape Thompson.

These rocks consist in general of shale and flaggy limestone. They contain chert beds in the Chitina Valley, on both shores of Cook Inlet, at Cape Lisburne, at Cape Thompson, and in the Noatak Valley. Volcanic material is present at the head of White River, in the upper Susitna Valley, and on Kenai Peninsula.

The writer believes that there is a marked unconformity at the base of the *Pseudomonotis*-bearing beds of Alaska and British Columbia. The evidence for this unconformity is as follows:

In the western part of the Chitina Valley, notably in the valley of Elliot Creek and in the hills between Rock and Copper Creeks, shale having the lithologic and faunal character of that of the McCarthy formation occurs not far above the top of the Chitistone limestone, thus apparently occupying the normal stratigraphic position of the Nizina limestone, over 1,000 feet thick, which elsewhere separates these two formations. In the vicinity of Skolai Pass, near the head of White River, the *Pseudomonotis* zone immediately overlies a Permian (?) limestone. There is consequently a hiatus here that is represented in the Nizina Valley, about 20 miles distant, by the Nikolai greenstone, the Chitistone limestone, and the Nizina limestone, which have an aggregate thickness of at least 7,000 or 8,000 feet. At Hamilton Bay, Kupreanof Island, in southeastern Alaska, the *Pseudomonotis* zone is separated from the older *Halobia* zone (the strata being inverted) by a conglomerate containing fossiliferous boulders of the older limestone. It is evident that the same unconformity is present on Cumshewa Inlet, Queen Charlotte Islands, where, according to Dawson,[55] the relations are as follows:

> On the southeast side of the South Arm flaggy argillites occur. They were observed to become conglomeratic in one place with fragments of the underlying [Triassic] limestone, which might be supposed to show that they belong to the coal-bearing [Cretaceous] series. They hold, however, the characteristic Triassic *Monotis*.

Further evidence of an unconformity at the base of the *Pseudomonotis* zone is indicated by the apparent absence at most places of the coral-bearing strata that belong below the *Pseudomonotis* zone and above the *Halobia* zone. The fact that in both Alaska and British Columbia the *Pseudomonotis*-bearing beds have a far wider distribution than the older *Halobia*-bearing beds and that the intervening coral-reef limestone is even more restricted, occurring only near the present continental margin, also suggests an Upper Noric transgression following a Lower Noric recession of the sea. The

[55] Dawson, G. M., Report on the Queen Charlotte Islands: Canada Geol. Survey Rept. Progress for 1878–79, p. 82B, 1880.

abrupt change in faunal character from the supposedly warm-water *Halobia* zone to the boreal *Pseudomonotis* zone also suggests a withdrawal of the Karnic Sea, followed by an Upper Noric transgression, presumably from the Arctic regions.

The fauna of the McCarthy formation as now known includes *Pseudomonotis subcircularis* (Gabb), *Halobia* sp., *Pecten* sp., and *Arniotites?* sp. The *Pseudomonotis*-bearing beds of the other Alaskan districts are correlated with the McCarthy formation on the basis of general lithologic similarity and sequence and also on the basis of the presence of *Pseudomonotis subcircularis.* This is the only fossil recognized in these beds at most localities, although a few fossils have been found associated with the *Pseudomonotis* at some places. These include *Clionites* (*Shastites*) sp. at the head of White River, *Arca?* sp. on the west coast of Cook Inlet, *Rhynchonella?* sp. and *Terebratula* sp. near the mouth of Nation River, and some undetermined pelecypods near Cape Lisburne.

The presence of *Pseudomonotis subcircularis* in these beds is sufficient evidence for their approximate correlation with the Brock shale of Shasta County, Calif., with the Swearinger slate of Plumas County, Calif., and with the *Pseudomonotis*-bearing slate and slaty limestone of the West Humboldt Range, Nev.

In British Columbia and Yukon there is an extensive development of *Pseudomonotis*-bearing beds that can be correlated on the basis of faunal content, as well as of stratigraphic sequence, with those of Alaska. They occcur in two well-defined belts—a western or coastal belt that includes Triassic areas in the Queen Charlotte Islands, on Vancouver and the adjacent islands, and at the north end of the Cascade Range; and an eastern or interior belt that is situated on the eastern front of the Rocky Mountains and that includes known Triassic areas on Pine, Peace, and Stewart Rivers.

The *Pseudomonotis*-bearing beds of the Queen Charlotte Islands, according to Dawson,[56] consist of flaggy calcareous argillite and thin limestone more than 1,000 feet thick. These beds are underlain by massive limestone and are overlain [57] by feldspathic sandstone, coarse conglomerate, and agglomeratic rocks which Dawson considered Cretaceous but which are now known to be Lower and Middle Jurassic.[58] These rocks have all been included in the Vancouver series. The contact of the argillite with the underlying limestone, although supposed to be in general conformable, is apparently unconformable in at least one locality, according to Dawson's description.[59] The fossils

[56] Dawson, G. M., Report on the Queen Charlotte Islands: Canada Geol. Survey Rept. Progress for 1878–79, pp. 48B, 55B, 58B, 59B, 61B, 62B, 63B, 82B, 1880.

[57] Idem, pp. 48B, 59B, 62B.

[58] McKenzie, J. D., South-central Graham Island, British Columbia: Canada Geol. Survey Summary Rept. for 1913, pp. 40–42.

[59] Dawson, G. M., op. cit., p. 82B.

listed from these beds include *Pseudomonotis subcircularis* (Gabb) an "extreme local variety" of "*Halobia lommeli?*," and *Arniotites vancouverensis* Whiteaves.

It is probable that the same horizon is present in the Vancouver series at the north end of Vancouver Island, where, according to Dawson,[60] flaggy limestone, calcareous argillite, black flinty argillite, etc., overlie a massive limestone and are overlain by sandstone, above which are volcanic beds. The section is closely similar to that of the Queen Charlotte Islands. The fossils from the flaggy limestones and argillites were described by Whiteaves[61] as including the following species:

Halobia (Daonella) lommeli? (extreme local variety).
Arcestes gabbi Meek.
Arniotites vancouverensis Whiteaves.
Arniotites sp.
Arniotites or Celtites sp.

It has been generally assumed that these fossils are Middle Triassic which they would undoubtedly be, at least the *Daonella* and the *Arcestes*, if the species have been correctly determined. It was the opinion of Frech[62] that the ammonites described as *Arniotites* are also indicative of Middle Triassic age, "*Arniotites vancouverensis*" probably being a *Celtites*, "*Arniotites* or *Celites* sp." being a *Celtites* related to *C. epolense* Mojsisovics, and "*Arniotites* sp." being a *Ceratites* related to *C. japonicus* Mojsisovics.

The writer doubts whether any of these fossils from Vancouver Island are Middle Triassic and believes that it is highly probable that they are all Upper Triassic. The reasons for this belief are as follows: Whiteaves expressed considerable doubt concerning the identification of *Halobia* (*Daonella*) *lommeli* and considered that the Vancouver Island specimens "may possibly represent an extreme local variety of this species."[63] He recognized the same "extreme local variety" as occurring in association with *Pseudomonotis subcircularis* in the flaggy limestone and argillite of the Queen Charlotte Islands. This form is probably identical with neither *Daonella lommeli* Wissman, of Europe, nor *Daonella dubia* Gabb, of Nevada, but is more likely an Upper Triassic species of *Halobia*. The fossils identified by Whiteaves as *Arcestes gabbi* Meek have been neither described nor figured and may possibly belong to some of the Upper Triassic species of *Arcestes* which had not been recognized

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[60] Dawson, G. M., Report on a geological examination of the northern part of Vancouver Island and adjacent coasts: Canada Geol. Survey Ann. Rept., new ser., vol. 2, pp. 9B, 26B, 73B, 76B, 83B, 89B, 1886.

[61] Whiteaves, J. F., On some fossils from the Triassic rocks of British Columbia: Contr. Canadian Paleontology, vol. 1, pt. 2, No. 3, pp. 134, 141, 146–147, pl. 19, figs. 3, 4, 1889.

[62] Frech, Fritz, Die zircumpacifische Trias: Lethaea geognostica, Teil 2, Band 1, pp. 490–491, 1908.

[63] Whiteaves, J. F., op. cit., p. 134.

in America at the time Whiteaves made his studies. *Arniotites vancouverensis* was described by Whiteaves from specimens found in the argillite of Queen Charlotte Islands that contains *Pseudomonotis subcircularis.* This species has been reported [64] also as occurring together with *Pseudomonotis subcircularis*, in the Parson Bay group of Harbledown Island. It probably occurs also in the argillite of the Cultus formation [65] on the west slope of the Cascades, where it is associated with *Aulacoceras?* cf. *A. carlottense* Whiteaves. The genus *Aulacoceras*, according to Mojsisovics, is known only in the Upper Triassic. The fossil from Robson Island, described by Whiteaves [66] as *Arniotites* sp., is closely related, according to Frech,[67] to *Ceratites japonicus* Mojsisovics of the Triassic of Japan. Although that species has been referred to the Ladinic,[68] it occurs in beds that apparently overlie those containing *Pseudomonotis ochotica.*[69] It should also be noted that *Arniotites* probably occurs in Alaska (see p. 30) in the upper part of the McCarthy formation.

The *Pseudomonotis* horizon of Alaska is probably represented on the islands east of Vancouver Island by the Parson Bay group,[70] which consists of "shales, argillites, impure limestones, calcareous sandstones and quartzites," which contain *Pseudomonotis subcircularis*, *Halobia*, *Natica?*, and *Arniotites vancouverensis*, and which rest on the lava, breccia, and tuff described as the Valdez group.

These rocks may be correlated also with the argillites of the Cultus formation,[71] which is exposed near the western base of the Cascade Range and which contains *Arniotites vancouverensis* Whiteaves? and *Aulacoceras?* cf. *A. carlottense* Whiteaves.

The argillite of Whipsaw Creek, near the headwaters of the Similkameen, on the crest of the Cascade Range, which was described by Dawson [72] as occurring in a syncline and as underlain by volcanic rocks that were correlated with those of the Nicola

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[64] Bancroft, J. A., Geology of the coasts and islands between the Strait of Georgia and Queen Charlotte Sound, British Columbia: Canada Geol. Survey Mem. 23 (No. 1188), pp. 75–76, pl. 9 (b), 1913.

[65] Daly, R. A., Geology of the North American Cordillera at the Forty-ninth parallel: Canada Geol. Survey Mem. 38, pt. 1, pp. 516–517, 1912.

[66] Whiteaves, J. F., op. cit., p. 147, pl. 19, fig. 3.

[67] Frech, Fritz, Die zircumpacifische Trias: Lethaea geognostica, Teil 2, Band 1, p. 490, 1908.

[68] Noetling, Fritz, Die asiatische Trias: Lethaea geognostica, Teil 2, Band 1, Lief. 2, pp. 195–196, 220, 1905.

[69] Mojsisovics, Edmund von, Ueber einige japanische Triasfossilien: Beitr. Palaeontologie Osterreich-Ungarns, Band 7, pp. 163–178, 1889.

[70] Bancroft, J. A., op. cit., pp. 75–77.

[71] Daly, R. A., op. cit., pp. 516–517.

[72] Dawson, G. M., Preliminary report on the physical and geological features of the southern portion of the interior of British Columbia: Canada Geol. Survey Rept. Progress for 1877–78, pp. 66B, 67B, 1879.

series and which contains fossils that Whiteaves[73] doubtfully referred to *Pseudomonotis subcircularis*, possibly also belongs at this horizon. It should, however, not be confused with the Middle Triassic beds (see p. 118) of Thompson River and of Nicola Lake (?), with which Dawson[74] correlated it.

Beds containing *Pseudomonotis subcircularis* occur in a more or less continuous belt along the eastern front of the Rocky Mountains of British Columbia and Yukon. The known localities are on upper Pine River;[75] on Peace River, about 27 miles below the junction of Finlay and Parsnip Rivers, where the rocks have been described by Selwyn[76] and by McConnell[77] as consisting of calcareous shale and impure limestone; and near the headwaters of Stewart River, where, according to Keele,[78] the beds include impure limestone, argillite, and quartzite, with *Pseudomonotis subcircularis*, "*Halobia lommeli*," and *Arpadites?*.

The generally accepted assignment of the *Pseudomonotis*-bearing beds of Alaska to the horizon of the Upper Noric of Europe and Asia is based on the close relationship of the Alaskan fossil identified as *Pseudomonotis subcircularis* (Gabb), with *Pseudomonotis ochotica* (Keyserling), which is the characteristic fossil of the boreal Upper Noric beds of Asia. This relationship was long ago shown by Teller[79] and by Mojsisovics.[80] Specimens from Cold Bay, on the Alaska Peninsula, have more recently been examined by Frech,[81] who has identified them as including both the typical form of *Pseudomonotis ochotica* (Keyserling) and also *Pseudomonotis ochotica* var. *sparicostata* Teller. Further confirmation of this correlation is found in the general similarity of the Alaskan Upper Triassic section as a whole to that of California and other regions.

GEOLOGIC HISTORY OF ALASKA IN TRIASSIC TIME

The youngest known Paleozoic rocks of Alaska consist of the Permian (?) limestone, which carries a fauna closely allied to that

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[73] Whiteaves, J. F., op. cit., pp. 127–132.

[74] Dawson, G. M., Report on the area of the Kamloops map-sheet, British Columbia: Canada Geol. Survey Ann. Rept., new ser., vol. 2, pp. 50B–137B, 1896.

[75] Whiteaves, J. F., Notes on some Jurassic fossils collected by G. M. Dawson in the Coast Range of British Columbia: Canada Geol. Survey Rept. Progress for 1876–77, p. 158.

[76] Selwyn, A. R. C., Report on exploration in British Columbia: Canada Geol. Survey Rept. Progress for 1875–76, pp. 75, 80, 97, 1877.

[77] McConnell, R. G., Report on an exploration of the Finlay and Omenica Rivers: Canada Geol. Survey Ann. Rept. for 1894, pp. 32C, 35C, 1896.

[78] Keele, J., Report on the upper Stewart River region, Yukon: Canada Geol. Survey Ann. Rept., new ser., vol. 16, pp. 14C, 15C, 17C, 1906.

[79] Teller, Friedrich, Die Pelecypod-Fauna von Werchojansk in Ostsiberien: Acad. imp. sci. St.-Pétersbourg Mém., 7th ser., vol. 33, No. 6, pp. 110, 113, 115, 1886.

[80] Mojsisovics, Edmund von, Arktische Triasfaunen: Acad. imp. sci. St.-Pétersbourg Mém., 7th ser., vol. 33, No. 6, p. 147, 1886.

[81] Frech, Fritz, Die zircumpacifische Trias: Lethaea geognostica, Teil 2, Band 1, p. 489, pl. 68, fig. 3a, 1908.

Interregional correlation of the Triassic

[After J. P. Smith, except for Alaska]

Series[a]	Stage[a]	Substage[a]	Interregional zone	Mediterranean region: German	Mediterranean region: Alpine	Arctic-Pacific region	Oriental region: Himalaya	Oriental region: Salt Range	American region: California	American region: Nevada	American region: Idaho	American region: British Columbia	Alaska: Chitina Valley	Alaska: Southwestern Alaska	Alaska: Southeastern Alaska	Alaska: Yukon Valley and northern Alaska
	Rhaetic.			Rhaetic.												
Upper Triassic. Bajuvaric.	Noric.		*Pseudomonotis ochotica.*	Keuper.	Noric limestone of Hallstatt. / *Pseudomonotis ochotica* in the Crimea.	*Pseudomonotis ochotica* slate of northern Siberia, Japan, and Indian Ocean.	*Monotis* beds. / Limestone with *Halorite.*		Brock shale.: Slate carrying *Pseudomonotis subcircularis, Rhabdoceras* and *Halorites.* / Hosselkus limestone.: *Spiriferina* beds. / Coral zone.	Star Peak formation.: *Pseudomonotis*-bearing slate, with *Rhabdoceras* and *Placites.*		*Pseudomonotis*-bearing slate.	McCarthy formation (shale with chert in lower part). Contains *Pseudomonotis subcircularis.* / Nizina limestone? (in part?)	Calcareous shale with *Pseudomonotis subcircularis.* / Chert (fossils not known). / Coral limestone of Iliamna Lake.	Upper limestone at Hamilton Bay with *Pseudomonotis.* / ? Limestone of Gravina Island (corals).	*Pseudomonotis* zone of Yukon River and Arctic Mountains.
Tirolic.	Karnic.	Tuvalic.	*Tropites subbullatus.*		Sandling beds with *Tropites subbullatus.*	*Halobia* slate of Eureka Sound and Spitzbergen.	*Halobia* beds.: *Tropites* limestone.		Zone of *Tropites subbullatus.*: *Juvavites* beds. / *Trachyceras* beds. / *Halobia superba* zone.	Limestone without characteristic fossils.			Nizina limestone (in part?) Chitistone limestone (with *Halobia* cf. *H. superba, Tropites, Juvavites, Arcestes,* etc.).		Limestone of Herring and Hamilton bays, with *Halobia* cf. *H. superba,* etc.	Limestone of Yukon, Firth, and Canning rivers, with *Halobia* cf. *H. superba, Clionites,* brachiopods, etc.
		Julic.			Raibl beds with *Trachyceras aonoides.*											
		Cordevolic.			Cassian beds with *Trachyceras aon.*	*Dawsonites* slate of Bear Island.	*Daonella* beds.: Beds with *Trachyceras tibeticum.*		Slate with *Halobia* cf. *H. rugosa.*			*Dawsonites* zone.			Limestone near Hamilton Bay with *Dawsonites* (not found in place).	
	Ladinic.	Longobardian.	*Daonella lommeli.*		Wengen beds with *Trachyceras archelaus.*		Beds with *Trachyceras archelaus* and *Daonella lommeli.*		Pit shale.: Shale and tuffs without determinable fossils.							
Middle Triassic. Upper Muschelkalk.		Fassanic.		Upper Muschelkalk.	Buchenstein beds with *Trachyceras reitzii.*	Ceratite slate of Japan with *Anolcites* and *Danubites.*	Beds with *Trachyceras cautleyi.*			*Daonella* zone in West Humboldt Range.		*Daonella* zone.				
Middle Muschelkalk. Dinaric.	Anisic.	Bosnian.	*Ceratites trinodosus.*	Middle Muschelkalk.	Reifling limestone.: Limestones of Han Bulog, Bakony, and the Schrey Alps, with *Ceratites trinodosus.* / *Ceratites binodosus* beds in the South Alps.	Beds of Ussuri Bay in eastern Siberia with *Monophyllites sichoticus.* / Mengilach beds (?) / *Daonella* limestone of Spitzbergen.	Upper Muschelkalk with *Ptychites rugifer* and *Ceratites trinodosus.*		Clay and siliceous shale with *Nevadites* cf. *N. whitneyi* and *Ceratites* cf. *C. humboldtensis.*	*Daonella dubia* zone with *Ceratites trinodosus.*						Slate of Brooks Mountain with *Daonella* and *Ceratites* (*Gymnotoceras*).
Lower Muschelkalk.	Hydaspic.	Balatonic.		Lower Muschelkalk with *Hungarites strombecki.*	Beds on Gulf of Ismid, in Asia Minor.		Lower Muschelkalk.									
Lower Triassic. Scythic.	Jakutic.		*Columbites* fauna.	Buntsandstein.	Werfen beds.: *Columbites* beds in Albania.	Olenek beds of northern Siberia.	*Stephanites* beds.	Ceratite beds.: Upper Ceratite limestone.	Ceratite-bearing limestones of Inyo Range.: Black limestone with *Parapopanoceras, Xenodiscus, Acrochordiceras,* and *Hungarites.*		Beds of Aspen Mountains.: *Columbites* zone.					
			Tirolites cassianus in Mediterranean region and Idaho.		Campil beds with *Tirolites cassianus.*		*Hedenstroemia* and *Flemingites* beds.	Ceratite sandstone.	Calcareous slate without fossils.		*Tirolites* zone.					
	Brahmanic.	Gangetic.	*Meekoceras* fauna in Siberia, India, California, and Idaho.		Seis beds with *Pseudomonotis clarai.*	*Proptychites* beds of Ussuri Bay, in southern Siberia. / *Posidonomya* limestone of Spitzbergen.	Meekoceras beds.	Ceratite marl. / Lower Ceratite limestone.	*Meekoceras* zone of Inyo County, Calif., with *Meekoceras gracilitatis, Ussuria, Pseudosageceras, Inyoites, Owenites, Nannites.*		*Meekoceras* zone.					
		Gandaric.					Otoceras beds.									

[a] These series, stage, and substage terms have not been adopted by the United States Geological Survey

of the Artinskian of Russia. The wide distribution of this limestone indicates that there was a period of profound submergence in late Paleozoic time, and that the sea probably extended over the larger part if not all of Alaska.

As Lower Triassic rocks have not been recognized in Alaska, it is believed that the end of Paleozoic time was marked by a widespread emergence, which continued until the beginning of the Upper Triassic.

The Permian or early Triassic lavas of the Pacific coastal belt, which are represented by the Nikolai greenstone of the Chitina Valley, the basic lava and tuff of the upper Susitna Valley, the ellipsoidal lava of Kenai Peninsula and Kodiak Island, the greenstone of the Iliamna-Clark Lake district, and the ellipsoidal lava of Hamilton Bay (and which may be represented by the greenstone associated with the Orca group of Prince William Sound and by some of the greenstones of southeastern Alaska), indicate a period of intense, widespread, and probably long-continued volcanic activity that probably occurred in early Triassic time. These volcanic deposits, so far as known, are not intercalated with marine sediments and presumably were poured out on land during the Permian or early Triassic period of emergence. The nonfossiliferous sedimentary rocks of the Orca group that are intercalated with the greenstone are, in the writer's opinion, not marine. The volcanic activity of this period apparently extended throughout the region south of the Alaska Range, from the Alaska Peninsula eastward and southward into British Columbia. Volcanic rocks of this date are not known north of the Alaska Range and probably were never present there, although their absence may be due to post-Triassic erosion. This sharp limitation of the distribution of these rocks along the present line of the major mountain axis of Alaska is very significant and, in the writer's opinion, clearly indicates that this line marked the northern limit of the supposed early Triassic volcanic activity.

Middle Triassic time was probably a period of emergence in Alaska, for Middle Triassic rocks are known only in Seward Peninsula.

The upper Triassic was a time of submergence, when limestone-forming seas swept over large Alaskan areas. The initial Upper Triassic submergence was probably in Karnic time, when limestone was deposited throughout the greater part if not all of the present Pacific Mountain region, being known along the Pacific coast from southeastern Alaska to Cook Inlet and in the Copper and Susitna Valleys. This limestone locally attains a thickness of at least 3,000 feet and, in general, is not interbedded with strata of other kinds. The fauna of these supposed Karnic beds of southern Alaska is of

the Mediterranean type and probably indicates warm-water conditions. The Karnic Sea probably advanced from the south. Limestones that were presumably synchronous with these but possibly were laid down in different basins that may have maintained a connection with the boreal sea are known in the present sites of the Rocky and Arctic Mountains or on the upper Yukon and the eastern part of the Arctic slope.

The sea probably receded in Lower Noric time from the greater part of Alaska, for rocks of supposed Lower Noric age are definitely known only in the vicinity of Iliamna Lake, where they are represented by limestone containing a warm-water coral-reef fauna.

The Upper Noric was the time of a great transgression of the sea, when the greater part if not all of Alaska was submerged. The supposed Upper Noric rocks consist of shale, impure limestone, and chert, with some local volcanic beds. They contain a boreal fauna that is allied to that of northern Asia and that possibly indicates a cold-water sea, in contrast with the preceding warm-water seas of Karnic and Lower Noric time. This marked difference in faunal conditions, together with the general absence of Lower Noric beds between the Upper Noric and the underlying Karnic strata and with the strong suggestions of an unconformity at the base of the Upper Noric beds (see pp. 21, 36, 124), indicates that there was an important recession of the sea at the end of Karnic time. The invading Upper Noric sea probably came from the northwest.

There was a general emergence of the land at the end of Noric time, when the sea probably retired beyond the present continental limits. Rhaetic and early Lias deposits are not known in Alaska, and it is believed that the continent stood above sea level from the end of Noric time until late Lias (Toarcian) time. Marked folding followed the deposition of the local Upper Triassic strata, but the date of this folding has not been determined more closely than post-Triassic and prior to Upper Jurassic. The beginning of the local record in Jurassic (probably Upper Lias or Toarcian) time was marked by a moderate submergence, accompanied or followed by intense volcanic activity along the present Pacific seaboard.

JURASSIC SYSTEM

GENERAL FEATURES

The Jurassic rocks of Alaska are for the most part restricted to the south-central and southwestern parts of the Territory (fig. 5), being best developed in a belt extending through the Alaska Peninsula, the Cook Island drainage basin, and the Chitina Valley. Within this region there is a great thickness of marine fossiliferous beds ranging in age from the Liassic to uppermost Jurassic and

constituting the most complete development of the Jurassic known in North America. The faunas are abundant and well developed and indicate the presence of many well known world-wide horizons. Fossil plants also occur in association with the marine fossils at several horizons in the Lower, Middle, and Upper Jurassic.

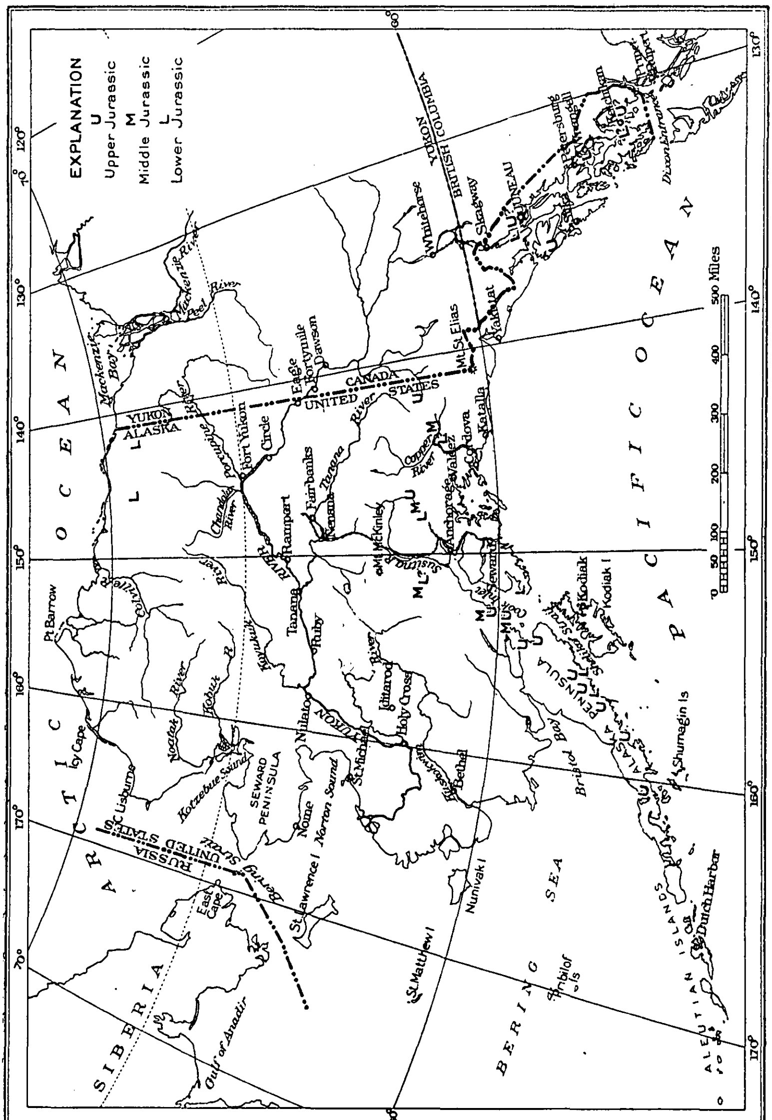

FIGURE 5.—Map of Alaska showing principal Jurassic localities

The broad extent and great thickness of the Jurassic strata in south-central and southwestern Alaska are in striking contrast with the poor development of the Jurassic in other parts of the Territory. Marine Jurassic beds apparently are entirely absent north of the

Alaska Range, except for the Lower or Middle Jurassic rocks of the eastern part of the Arctic slope. No undoubted Jurassic rocks have been found anywhere in the Kuskokwim and Yukon Basins, except on tributaries heading south of the Alaska Range. The only Jurassic rocks that have been reported from northern Alaska are the marine Lower or Middle Jurassic beds of the eastern part of the Arctic slope and the nonmarine plant-bearing beds of the Corwin formation near Cape Lisburne, which are now believed to be probably Cretaceous. (See p. 467.) In southeastern Alaska there are also some plant-bearing and other nonmarine deposits that may be of Jurassic age. At other localities in various parts of Alaska, but chiefly in the central and southern parts, there are metamorphic rocks of possible Jurassic age whose fossils are such that they can not be positively affirmed to be Jurassic or even Mesozoic. For most of these metamorphic rocks the probabilities are more strongly in favor of other than Jurassic age, and the rocks have been here described accordingly.

The known or supposed Lower Jurassic rocks of Alaska include fossiliferous marine tuff exposed at Seldovia Bay and Port Graham on Kenai Peninsula, possibly some porphyry and tuff on the west coast of Cook Inlet, shale and sandstone that overlie the Upper Triassic rocks of Cold and Alinchak bays on Alaska Peninsula, the marine tuff of the Matanuska Valley and Talkeetna Mountains, possibly the volcanic rocks of the Skwentna group of the Alaska Range, possibly the tuffaceous conglomerate near Taral in the Chitina Valley, and perhaps some of the melaphyre breccia and tuff of southeastern Alaska. The Kialagvik formation of the Alaska Peninsula and the Kingak shale of the Arctic slope may also be partly or wholly Lower Jurassic.

The oldest of the Middle Jurassic rocks of Alaska may include the Kialagvik formation of the Alaska Peninsula and the Kingak shale of the Arctic slope. A slightly higher horizon in the Middle Jurassic is represented by the Tuxedni sandstone of Cook Inlet, the sandstone that carries the Tuxedni fauna in the Matanuska Valley, the Tordrillo formation of the Alaska Range, and the fossiliferous tuffaceous slate near the mouth of Chitina River. There are also suggestions that the Tuxedni fauna may be present on the Alaska Peninsula. It is also possible that some of the volcanic rocks of southeastern Alaska may be Middle Jurassic.

The oldest of the Upper Jurassic formations of Alaska is the Chinitna shale of Cook Inlet. The fauna of the Chinitna shale has been recognized in the Shelikof formation of the Alaska Peninsula and in shale underlying the Naknek formation in the Matanuska Valley. A younger horizon in the Upper Jurassic is represented by the Naknek formation of the Alaska Peninsula and Cook Inlet. The fauna

of the Naknek formation has been clearly recognized in some shale and sandstone of the Matanuska Valley, and it is believed to be also represented by some of the *Aucella*-bearing beds of the Nutzotin Mountains and of southeastern Alaska. The Kennicott formation of the Chitina Valley was formerly referred to the Upper Jurassic, but the writer believes that its fauna is entirely different from that of the Naknek formation and that it is Lower Cretaceous. (See p. 335.) The Corwin formation of the Cape Lisburne district carries a flora somewhat similar to that of the Kennicott formation and was formerly regarded as Upper Jurassic, but the writer believes that it also is probably Lower Cretaceous.

LOCAL SECTIONS

COOK INLET

GENERAL FEATURES

The most complete known section of Jurassic rocks in Alaska, or in fact in North America, is on Cook Inlet, where most of the recognized Alaskan horizons are represented by beds that attain great thickness, contain abundant and well-preserved faunas and floras, and for the most part show clearly their stratigraphic relations. The Cook Inlet section will therefore be described in detail, as the standard and typical section for the Alaskan Jurassic, and the other local sections will subsequently be described and interpreted in terms of their relation to it.

Jurassic rocks occur upon both shores of Cook Inlet, but the sections exposed on the opposite sides are strikingly unlike. The known Jurassic of the east shore of Cook Inlet includes only Lower Jurassic marine-laid tuff, the Middle and Upper Jurassic not being represented, except possibly by part of the slate and graywacke of the Kenai Mountains (pp. 482–483). The section on the west shore includes lava and tuff that may represent the Lower Jurassic, overlain by Middle and Upper Jurassic formations, aggregating many thousand feet of fossiliferous marine strata.

The sequence of Jurassic rocks on the west coast of Cook Inlet, as represented in the peninsula between Chinitna and Iniskin Bays, was given by Moffit[82] as follows:

[82] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, p. 120, 1922.

Jurassic rocks on west coast of Cook Inlet

Age	Formation	Lithologic character	Thickness (feet)
Upper Jurassic.	Naknek formation.	Massive light-colored sandstone, arkose, and tuff.	3,000
		Gray shale with sandstone beds.	1,500
	Chisik conglomerate.[a]	Massive conglomerate with boulders, possibly represented in many places by grit and arkose.	290
	Chinitna shale.	Fairly homogeneous argillaceous gray, black, and reddish shales with subordinate calcareous and arenaceous beds.	2,300
Middle Jurassic.	Tuxedni sandstone.	Arenaceous gray shale with subordinate sandstone beds.	8,000
		Sandstone, shale, arkosic sandstone, and conglomerate.	
Lower Jurassic.		Volcanic rocks; porphyry and tuff (basaltic and andesitic lavas and tuffs).	1,000?

[a] Now classified as basal member of Naknek formation.

The rocks of this section overlie or are faulted against Upper Triassic strata that crop out west of them and are overlain unconformably at one or two localities by Tertiary beds. Cretaceous rocks are not present on Cook Inlet.

LOWER JURASSIC

TUFF OF KENAI PENINSULA

Historical review.—The oldest Jurassic horizon known on Cook Inlet is represented by the Lower Jurassic tuff that is well developed on the shore of Kenai Peninsula from Point Bede to Seldovia Bay. It probably includes the " compact Neocomian limestone " that Eichwald[83] mentioned as occurring near English Bay and as containing *Arcomya crassissima* and *Janira.* These rocks were first referred to the Lower Jurassic by Stanton and Martin,[84] who discussed briefly the occurrence and probable age of the fossiliferous beds. The lithologic character of the rocks was described in somewhat greater detail by Moffit,[85] whose account includes the previously unpublished lists of the fossils collected by Stanton and Martin, together with a discussion of their age contributed by Stanton. Brief mention of the occurrence of these rocks has been made by Grant and Higgins,[86] and also by Grant.[87] They comprise the Lower Jurassic tuff of

[83] Eichwald, Eduard von, Geognostisch-palaeontologische Bemerkungen über die Halbinsel Mangischlak und die aleutischen Inseln, pp. 91–92, St. Petersburg, 1871.

[84] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 396–397, 1905.

[85] Moffit, F. H., Gold fields of the Turnagain Arm region: U. S. Geol. Survey Bull. 277, pp. 20–22, 1906.

[86] Grant, U. S., and Higgins, D. F., Preliminary report on the mineral resources of the southern part of Kenai Peninsula: U. S. Geol. Survey Bull. 442, p. 168, 1910.

[87] Grant, U. S., The southeastern part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 211, 228, 1915.

Kenai Peninsula as described and mapped by Martin,[88] whose account includes a long description of the lithologic character of the formation, full lists of the fossils collected by Stanton, Martin, and Grant, and a discussion of age and correlation in which there is a short statement by Stanton regarding the probable relations of the fauna.

Stratigraphic description.—The Lower Jurassic rocks of Kenai Peninsula consist of tuff and volcanic agglomerate which are interbedded with thinner and less numerous strata of sandstone, shale, and limestone. The presence of marine shells indicates the marine deposition of at least part of the series. The absence of any sharp break in the sequence or of anything that indicates a considerable change in the character of the sedimentation suggests that the entire series may have been laid down in marine waters.

Volcanic beds are distributed through all parts of the formation, there being repeated alternations between well-stratified sedimentary detritus and the coarser and rudely stratified tuff and agglomerate. Some of the agglomerate is very coarse, fragments 5 feet in diameter having been observed. The tuff shows considerable variation in composition, rhyolite, andesite, and quartz ceratophyre tuff having been noted.

No stratigraphic section has been measured, and the thickness of the beds can therefore be stated only approximately. The available data on which an estimate of thickness can be based are the general width of the outcrop and the amount of dip. The dip is apparently monoclinal and is northwestward, ranging from 10° to 80°. With an average dip of 30°, the thickness of the strata would be about 8,000 feet. This is probably much in excess of the true thickness, for the beds are broken by normal faults. As the amount of movement on these faults has not been determined, it is impossible to surmise the aggregate amount of repetition by faulting. It is safe, however, to assume a thickness of at least 1,000 feet, and the beds are probably 2,000 or 3,000 feet thick.

The base and top of this formation have not been recognized. Upper Triassic rocks, which probably immediately underlie these Lower Jurassic beds, lie east of them on the shores of Port Graham, but the observed contacts appear to be faults, and therefore the nature of the initial deposition is not known. The next younger rocks locally present are Tertiary and overlie the Lower Jurassic rocks with a profound unconformity.

Age and correlation.—The Lower Jurassic tuffs of Kenai Peninsula have yielded the fossils listed below:

[88] Martin, G. C., The western part of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 63–67, pl. 3, 1915.

Fossils from Lower Jurassic tuffs of Kenai Peninsula [a]

	2977	2978	2979	6385	6384	2980	2981	7237	7236	2982	2983
Montlivaultia?					×						
Astrocoenia?							×				
Undetermined coral								×			
Pentacrinus		×									
Pinna cf. P. expansa Hyatt		×					×				
Perna??						×					
Ostrea				×							
Ostrea or Gryphaea											×
Gryphaea					×	×					
Cardinia sp. a	×		?			×	?				
Cardinia? sp. b		×									
Cardinia			×	×							
Myophoria?		×									
Trigonia sp. a	×	×									
Trigonia sp. b		×									
Trigonia?							×				×
Pecten sp. a		×									×
Pecten sp. b						×	×			×	
Pecten sp. c							×				
Pecten sp. d										×	
Pecten (small ribbed form)									×		
Pecten (large smooth form)									×		
Pecten					×						
Pecten					×						
Anomia?									×		
Pleuromya					×						
Anatina (Cercomya)					×						
Pleurotomaria?			×								
Pseudomelania?						×					
Natica?					×				×		
Arietites?							×				
Undetermined ammonite		×	×								

[a] Identified by T. W. Stanton.

2977 (904). West side of Seldovia Bay, opposite village, one-fourth mile southeast of 2978. T. W. Stanton, 1904.

2978 (905). Point Naskowhak, at entrance to Seldovia Bay. T. W. Stanton, 1904.

2979 (906). Three-fourths of a mile west of 2978. T. W. Stanton, 1904.

6385 (G684). East shore of Cook Inlet, 1 mile southwest of Point Naskowhak. U. S. Grant, 1909.

6384 (G682). East shore of Cook Inlet, about one-third of the way from Point Naskowhak (which is at the south entrance to Seldovia Bay) to Dangerous Cape. U. S. Grant, 1909.

2980 (907A). Shore of Cook Inlet, 2 miles west of Seldovia Bay. T. W. Stanton, 1904.

2981 (907B). Same locality as 2980, but 200 feet higher. T. W. Stanton, 1904.

7237. About 2¾ miles southwest of Point Naskowhak. G. C. Martin, 1911.

7236 (115). Three miles southwest of Point Naskowhak. G. C. Martin, 1911.

2982 (908). Shore of Cook Inlet, 3 miles west of Seldovia Bay. Lawrence Martin, 1904.

2983 (909). Port Graham, 1½ miles southeast of coal mine. T. W. Stanton, 1904.

The evidence of the fossils on the age of these rocks has been discussed by Stanton as follows:

The evidence can not be considered final on account of the imperfect state of preservation, the small number of species, and the lack of definitely characteristic forms, but so far as I can judge from the present collections and from the field relations of the beds containing them it seems most probable

that all these small lots belong to one general fauna and that the age of the beds is Lower Jurassic. The fossils are certainly Mesozoic, and the collections include no species in common with the Middle and Upper Jurassic faunas, which are so well developed in thick formations on the west side of Cook Inlet and on the Alaska Peninsula, and contain several types that are apparently older than any found in those faunas. On the other hand, the only evidence suggesting the Triassic age is the presence of shells doubtfully referred to *Myophoria* from superficial characters, and this evidence is overbalanced by the Jurassic affinities of the other species.

The exact position of these rocks relative to that of the other Jurassic formations of Alaska has not been definitely established. The absence of other Jurassic strata above or below them on Kenai Peninsula of course removes the possibility of the most satisfactory determination of their relative position. It is also unfortunate that in none of the other and more complete Alaskan Jurassic sections have rocks been found that can be positively correlated with this formation. The Lower Jurassic of Alaska is probably best represented on the Alaska Peninsula (pp. 181–186), but our knowledge of that section is very incomplete, and the fauna of these beds has not yet been found there. The Matanuska Valley section (pp. 219–223) contains strata very similar to these, both in lithology and in faunal character, but the correlation has not yet been established beyond all doubt. The Lower Jurassic tuff of the Matanuska Valley, which the writer believes will yet prove to be the equivalent of these beds, also contains a rather sparse fauna of none too well established age. It is, however, overlain by Middle Jurassic strata. The section on the west coast of Cook Inlet includes nonfossiliferous volcanic rocks (pp. 137–139), which have been correlated with these beds on the basis of lithologic resemblance, and those rocks are also overlain by fossiliferous Middle Jurassic strata identical with those of the Matanuska Valley. It is consequently evident that the available stratigraphic evidence points strongly toward the Lower Jurassic age of this formation but does not help in determining its position within the Lower Jurassic.

PORPHYRY AND TUFF OF THE WEST COAST OF COOK INLET

Historical review.—Volcanic rocks that are somewhat similar to the Lower Jurassic tuff of Kenai Peninsula crop out in a more or less continuous belt parallel to the west coast of Cook Inlet from Tuxedni Bay to Bear Cove. These rocks form the volcanic part of the "pre-Jurassic crystallines and intrusives" as mapped and very briefly described by Martin[89] and were described and mapped in

[89] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, p. 38, pl. 4, 1905.

much greater detail by Martin and Katz[90] as "Lower Jurassic (?) porphyries and tuffs." The stratigraphy and structure of these rocks at various localities between Tuxedni and Kamishak Bays have been discussed by Martin.[91]

The distribution, field occurrence, lithologic character, structure, age, and interrelations of the supposed equivalents of these lavas in the Chulitna and Mulchatna Valleys west of Clark Lake have been discussed by Smith.[92]

The occurrence of these rocks in the vicinity of Tuxedni Bay[93] and in the vicinity of Iniskin and Chinitna Bays[94] was indicated by Moffit in columnar sections and on geologic maps, but no description was given.

A brief general account of the occurrence of these porphyries and tuffs in the area west of Kamishak Bay has been given by Mather,[95] who also described some basic lavas that underlie and overlie shale, sandstone, grit, and tuff that carry the fauna of the Tuxedni sandstone.

Lithologic character and stratigraphic relations.—The supposed Lower Jurassic tuff of the west coast of Cook Inlet is well exposed on the south shore of Cottonwood Bay, where there are outcrops revealing a thick series of volcanic beds, including both flows and tuffs, which overlie the Upper Triassic Kamishak chert with apparent conformity. Amygdaloidal basalt and volcanic agglomerate are among the more characteristic rocks seen at this locality. Similar rocks are exposed on the north shore of Iliamna Bay, where they include fine-grained green and gray felsitic rocks and tuffs, in part cherty, invaded by large dikes of quartz-feldspar porphyry; and also on the south shore of Ursus Cove, where quartz porphyry tuff, andesite, and andesitic and rhyolitic agglomerates are present. The belt also extends northward from Iliamna Bay, being exposed on the west and north shores of Iniskin Bay, where basalt, gabbro, and tuff are present; near the head of Chinitna Bay, where it includes olivine basalt and tuff; and on the upper arm of Tuxedni Bay, where quartz porphyry, augite andesite tuff, and quartz porphyry tuff were seen.

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[90] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 50–59, pl. 2, 1912.

[91] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 43–49, 1921.

[92] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 46, 104–112, pl. 5, 1917.

[93] Moffit, F. H., Geology of the vicinity of Tuxedni Bay, Cook Inlet: U. S. Geol. Survey Bull. 722, p. 142, pl. 2, 1922.

[94] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, p. 120, pl. 3, 1922.

[95] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, pp. 164–165, 1925.

Volcanic rocks of the same general character occur north of Iliamna Lake from the valley of Chekok River northward through the valleys of Lower Tazimina and Kontrashibuna Lakes to Lake Clark, possibly extending thence westward; and at several detached areas on the south shore and on some of the islands of Iliamna Lake below Pile Bay. These rocks may or may not be of the same age.

The volcanic rocks as seen on the south shore of Cottonwood Bay overlie the Triassic Kamishak chert. The relations are apparently those of conformable stratigraphic succession, for not only was no erosional break observed, but there is a more or less gradual change in lithologic character from the fine-grained homogeneous cherty beds below to the coarser heterogeneous volcanic accumulation above. The exposures on the east shore of Iniskin Bay show that these rocks lie unconformably beneath the Middle Jurassic Tuxedni sandstone. The local relations thus indicate that these rocks are either very high in the Triassic or low in the Jurassic.

No Lower Jurassic faunas have been found west of Cook Inlet, either in the beds here described or in any others, but the volcanic beds on the west shore of Cook Inlet and possibly also those on Iliamna and Clark Lakes may be correlated with the tuff at Seldovia and assigned to the Lower Jurassic, on the basis of similar lithology and sequence. This correlation is regarded as probable for the rocks on Cottonwood and Iliamna Bays. The assignment of the rocks west of the mountains to the Lower Jurassic is dependent on a correlation through the rocks on Iliamna Bay and is subject to more or less doubt.

The apparent absence of fossils in these rocks may be explained by more intense volcanic activity than in the vicinity of Seldovia, or by terrestrial rather than marine deposition west of Cook Inlet. It should be noted that these rocks differ from their supposed equivalents on Kenai Peninsula in containing a larger proportion of lava.

The basic lava on the west shore of Kamishak Bay which Mather[96] described as underlying shale, sandstone, grit, and tuff that contain fossils indicative of the Middle Jurassic fauna of the Tuxedni sandstone, and possibly the tuff that is interbedded with the fossiliferous strata, as well as the basic lava that overlies them, may belong with the rocks here under discussion. Part or all of the supposed Lower Jurassic porphyry and tuff of the west coast of Cook Inlet may therefore be Middle Jurassic. The writer believes, however, that the general absence of volcanic material at the horizon of the Tuxedni sandstone indicates that the volcanic beds west of Kamishak Bay either underlie the Middle Jurassic rocks or are involved with them in structural disturbances.

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[96] Mather, K. F., op. cit., pp. 165–166.

MIDDLE JURASSIC

TUXEDNI SANDSTONE

Historical review.—The Tuxedni sandstone is the lowest of the apparently conformable Middle and Upper Jurassic formations that are exposed in the cliffs on the west coast of Cook Inlet. It was first described under this name by Martin and Katz,[97] although rocks belonging in it had previously been described by several geologists. The first mention of rocks belonging to this formation was apparently made by Eichwald,[98] who described "hard black sandstones with ammonites" as occurring on Chisik ("Chasik") Island. The fossils described by Eichwald[99] as occurring in the "Neocomian or Gault" of "Chasik Island" and "Tukusitnu" [Tuxedni] Bay and probably at least part of those from undescribed localities on Cook Inlet and "Aläska" or Alaska Peninsula belong in this formation. The rocks on Tuxedni Bay that constitute the type section of this formation have been briefly described by Dall,[1] and the fossils that Dall collected from these beds in 1895 were examined by Hyatt,[2] who without enumerating the species in detail discussed the relations of some of the more characteristic forms and referred the fauna to the "Inferior Oolite." The Tuxedni sandstone constitutes the lower part (zones A, B, and C) of the "Enochkin formation" as described by Martin[3] and also by Stanton and Martin.[4] Both of these descriptions contain detailed stratigraphic sections and lists of fossils, and the latter includes also a discussion of the probable position of these rocks in the European section. The flora of these rocks was considered briefly by Knowlton[5] in a discussion of the Jurassic-Cretaceous problem of Oregon and California. The description of this formation by Martin and Katz[6] is largely a summary of the earlier descriptions by Stanton and Martin and by Martin, but adopts a new classification of the beds, and includes some details not presented before, among which is a previously unpublished discussion of the fossil plants contributed by Knowlton.

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[97] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59–64, pl. 2, 1912.

[98] Eichwald, Eduard von., Geognostisch-palaeontologische Bemerkungen über die Halbinsel Mangischlak und die aleutischen Inseln, p. 91, St. Petersburg, 1871.

[99] Idem, pp. 138–200.

[1] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 869–870, 1896.

[2] Hyatt, Alpheus, Report on the Mesozoic fossils (appendix to Dall's Report on coal and lignite of Alaska): U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 907–908, 1896.

[3] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 38–44, 1905.

[4] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 397–402, 1905.

[5] Knowlton, F. H., The Jurassic age of the "Jurassic flora of Oregon": Am. Jour. Sci., 4th ser., vol. 30, pp. 49–50, 1910.

[6] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59–64, pl. 2, 1912.

The description of the Tuxedni sandstone given by Martin [7] in a discussion of the oil fields of Cook Inlet includes a brief general description of the formation, followed by detailed statements concerning the stratigraphic relations and structure on Tuxedni, Chinitna, and Iniskin Bays. It is chiefly compiled from information contained in the report by Martin and Katz.

A geologic reconnaissance in the vicinity of Tuxedni Bay was made in 1920 by Moffit,[8] who has given a brief general description of the Tuxedni sandstone. A detailed geologic investigation of the peninsula between Chinitna and Iniskin Bays was made by Moffit in 1921. A preliminary report on this investigation contains a description of the Tuxedni sandstone, with a generalized stratigraphic section of the formation which indicates that its thickness is more than 8,000 feet.[9]

Rocks that are supposedly equivalent to the Tuxedni sandstone, though of different composition and apparently interbedded with volcanic strata, were described by Mather [10] as occurring on the west shore of Kamishak Bay near Amakdedori. The description included a brief account of the character and the stratigraphic and structural relations of the rocks, with a list and discussion of some fossils by Stanton.

Stratigraphic description.—The Tuxedni sandstone, which rests unconformably upon the lava and tuff of probable Lower Jurassic age as described on page 138, consists predominantly of sandy beds but contains many thin strata of shale and limestone and at least one bed of coarse conglomerate. Its thickness at the type locality on Tuxedni Bay, according to the writer's estimate, is at least 1,500 feet and may be 2,000 feet or more. Moffit states that the thickness is possibly 3,000 feet on Tuxedni Bay and may be 8,000 feet in the Iniskin-Chinitna Peninsula. Fossils are abundant, a large and highly characteristic marine molluscan fauna ranging throughout the formation and terrestrial plants having been found in the marine deposits at several horizons.

The following section is exposed on the south shore of the western arm of Tuxedni Bay. The base of the section is about 2 miles west of Fossil Point, near an obscure contact with older volcanic rocks that are probably Lower Jurassic. This contact is possibly a fault; consequently it is not certain that the section includes the lowest beds of the Tuxedni sandstone.

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[7] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 43–48, pl. 8, 1921.

[8] Moffit, F. H., Geology of the vicinity of Tuxedni Bay, Cook Inlet: U. S. Geol. Survey Bull. 722, pp. 143–144, pl. 2, 1922.

[9] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, pp. 120–122, pl. 3, 1922.

[10] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, pp. 165–166, 1925.

Section of part of Tuxedni sandstone on south shore of Tuxedni Bay

	Feet
1. Shaly sandstone with scattered fossils, *Inoceramus*, *Trigonia*, *Sphaeroceras*, *Phylloceras*, etc. (lot 2993)	55
2. Black sandstone with small white angular grains	8
3. Hard gray sandstone	1
4. Black sandstone with *Inoceramus ambiguus*, *Stephanoceras* cf. *S. humphriesianum*, *Sphaeroceras oblatum*, etc. (lot 3995)	3
5. Dark shale	8
6. Soft coarse black sandstone with white grains (lot 10519)	39
7. Fine-grained gray shale with *Sphaeroceras oblatum*, *Belemnites*, etc. (lot 2996 at base and lot 10517)	18
8. Fine-grained gray shale	35
9. Bands of sandstone and shale	3½–6
10. Dark soft shaly rock with coarse grains	10
11. Dark limestone with abundant fossils, *Sphaeroceras cepoides*, *Pleuromya*, etc. (lots 2997 and 10516)	2–4
12. Dark shale	3
13. Dark conglomerate rock (arkose)	7½
14. Dark shale with conglomerate bands and with fossils (lot 2998)	26
15. Sandstone	1
16. Gray shale	15
17. Sandstone	2
18. Shale with scattered fossils (lot 10520)	12½
19. Sandstone and shale with *Stephanoceras carlottense*, *S. richardsoni*, *Sphaeroceras cepoides*, *Lytoceras*, *Phylloceras*, and many other fossils (lot 3000)	3–3½
20. Shale with concretionary bands	10
21. Concealed by a fault	100±
22. Gray shale with numerous sandstone and concretionary bands and a few fossils, including *Stephanoceras* cf. *S. humphriesianum* (lot 3013, near top)	100
23. Gray shale with sandstone and concretionary bands	150
24. Gray sandstone with *Inoceramus ambiguus* and a few other bivalves at base (lot 3001)	1
25. Limestone conglomerate with clavellate and undulate Trigonias, etc. (lots 3002 and 10521)	1
26. Gray sandstone	3½
27. Dark-gray fossiliferous sandstone	1
28. Gray sandstone with many small fossils (lot 3303) at base	11
29. Fossiliferous conglomerate with *Belemnites*	2
30. Shaly sandstone with *Inoceramus lucifer* and *Lima* cf. *L. gigantea* (lot 3005)	52
31. Sandy shale with a few thin fossiliferous sandstone bands (lot 3006)	35
32. Indurated ledges of argillaceous sandstone 1 to 4 feet thick, alternating with somewhat thicker beds of fossiliferous clay (lot 3008, upper part)	25
33. Shale with abundant ammonites, *Stephanoceras*, *Harpoceras*, etc. (lot 3009)	20

	Feet
34. Indurated bands of sandstone in ledges 1 to 1½ feet thick, alternating with thicker beds of shale	14
35. More or less sandy shale weathering yellowish. Fossils (lot 3011) in lower 10 feet	100
36. Sandstone with clay partings with abundant *Lima* cf. *L. gigantea* and other fossils (lot 3012 from 3½-foot band of grit at top)	36
37. Softer sandstone and shale to base of exposure, partly covered by shale talus	100
	1, 128

The top of this section is at Fossil Point, south of which the rocks are concealed in the low ground on the west shore of the bay. Higher beds belonging in the Tuxedni sandstone are exposed at the northwest end of Chisik Island. The concealed interval, beneath the waters of the bay, is of unknown magnitude but probably does not exceed a few hundred feet and may be so small as to be negligible. The absence on the mainland of a characteristic bed of conglomerate that crops out on Chisik Island indicates that the sections on the mainland and on the island do not overlap, although they carry essentially the same fauna.

The lowest rocks exposed at the northwest end of Chisik Island consist of concretionary shale that yielded the fossils of lot 3014. These rocks are overlain by coarse massive conglomerate, at least 200 feet thick, that includes lenses of sandy shale with fossiliferous concretions near its base. This conglomerate and the associated shale were erroneously referred to the Chinitna shale by Martin and Katz.[11] The conglomerate is overlain by fossiliferous concretionary shale from which the fossils of lots 3015 and 2992 were collected. This shale was not measured but is possibly several hundred feet thick. It is overlain by the Chinitna shale, which will be described below. The total thickness of the formation as exposed on Tuxedni Bay is probably at least 1,500 or 1,600 feet and may be as much as 2,000 feet, according to the writer's estimate, or 3,000 feet according to Moffit, if there is no duplication of beds in the concealed intervals.

The Tuxedni sandstone of the peninsula between Chinitna and Iniskin bays was described by Moffit[12] as follows:

The Tuxedni sandstone is not a homogeneous sandstone formation. It consists principally of sandstone and sandy shale but includes also conglomerate, grit, arkose, and, in the type locality, limestone. In general the lower part of the formation shows all the rocks mentioned, but the upper part is made up of sandy shale with which thin beds of sandstone in sub-

[11] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 66, pl. 2, 1912.

[12] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, pp. 120–121, 1922.

ordinate amount and rare conglomerate beds are interstratified. A generalized section based on observations of the formation in different parts of the district follows.

Generalized section of the Tuxedni sandstone in the Iniskin-Chinitna Peninsula

	Feet
Shale	1,075
Coarse gray sandstone	75
Shale	1,000
Coarse conglomerate.	
Shale	300
Gray sandstone.	
Shale	1,000
Coarse conglomerate	20
Thin shale.	
Heavy sandstone.	
Dark shale	1,200
Fine-grained gray sandstone with small beds of shale and sandy shale	1,500
Conglomerate	30
Sandy beds, including sandstone, sandy shale, and conglomerate.	1,800
Dark shale, sandy shale, and thin sandstones	
	8,000+

Study of the Tuxedni sandstone during the summer of 1921 shows that the formation is much thicker than earlier work in Cook Inlet seemed to indicate. No single section is known where the thickness of all the beds can be measured consecutively. The evidence of the thickness is therefore obtained from a number of incomplete sections in different localities and is subject to errors arising from incorrect correlation of beds in these sections and also from possible duplication of beds through faulting or folding. Furthermore, the base of the Tuxedni sandstone has never been unmistakably recognized in this district, although the top, determined solely on paleontologic evidence, was seen in a few places. The combined sections from all of the localities indicate a maximum thickness of 8,000+ feet for the formation. These figures are large and represent a thickness much greater than the formation attains elsewhere on Cook Inlet, so that some doubt is felt as to their correctness, although they are comparable with the thickness of the overlying Upper Jurassic rocks in that region.

The following section on the east shore of Iniskin Bay probably includes the basal beds of the formation, but the concealed intervals are very large, less than half of the total thickness of the formation being represented, and the contact with the overlying formation is probably cut off by a fault.

Section of Tuxedni sandstone on east shore of Iniskin Bay

	Feet
"Zone C":	
Sandy shale with many *Belemnites* and other fossils	50
Concealed	20
Soft shale	20
Dark-drab shale with scattered fossils	33
Hard calcareous shale full of fossils, principally *Inoceramus*, *Pleuromya*, and other pelecypods	2
Black sandstone	1
Dark shale	5
Black sandstone	1
Dark shale with many fossils	12
Reddish limestone	½
Dark shale with many fossils	14
Dark shale with scattered fossils	62
Dark soft sandstone with streaks of conglomerate	10
Concealed.	
"Zone B":	
Shale with several fossil bands containing *Trigonia doroschini*, etc	50
Concealed.	
"Zone A":	
Shale with several fossil beds each 10 to 25 inches thick and packed with fossils; *Trigonia doroschini*, *T. devexa*, etc	30
Concealed.	
Shale	12
Coarse conglomerate	20
Unconformity.	

Beds equivalent to the Tuxedni sandstone in age may be present on the west shore of Kamishak Bay near Amakdedori, where Mather found a series of sediments about 500 feet thick comprising dark carbonaceous shale, sandstone, grit, and volcanic tuff, which are underlain and overlain by dense basic lava overthrust upon the rocks of the Naknek formation. Some of the more calcareous beds are crowded with fragments of shells, chiefly pelecypods but with a few *Belemnites*. The fossils of lot 12101 were obtained from one of these beds.

Age and correlation.—The fossils of the Tuxedni sandstone, as represented in the following table, include a large number of marine mollusks, most of which belong to undescribed species, and a few fossil plants.

Fossils from Tuxedni sandstone of Cook Inlet [a]

	3010	3012	3011	3009	3008	3006	3007	3005	3003	3002	10521	3001	3004	3013	3000	10520	2998	2999
Cladophlebis																		
Marattiopsis or Danaeopsis																		
Sagenopteris göppertiana Zigno					b													b
Sagenopteris göppertiana?																		
Sagenopteris																		
Sagenopteris?																		
Macrotaeniopteris californica Fontaine																		
Nilsonia orientalis Heer																		
Nilsonia																		
Pterophyllum rajmahalense Morris																		
Pterophyllum rajmahalense?																		b
Pterophyllum or Zamites																		
Fieldenia nordenskiöldi Nathorst?																		
Fieldenia?																		
Pagiophyllum?																		
Phoenicopsis?																		
Stem (coniferous)																		
Stems																		
Fossil wood															b			
Serpula		a																
Rhynchonella				a											a			a
Terebratula (large broad form)							a											
Terebratula																		
Grammatodon	a			a			a							a	a		a	
Grammatodon? sp. a																		
Grammatodon? sp. b																		
Grammatodon?																		
Cucullaea																		
Cucullaea??																		
Arca	a																	
Arca?																		
Pinna (more slender than P. expansa and with longitudinal striae)																		
Pinna			a											a			a	a
Gervillia (large species)	a																	
Inoceramus ambiguus Eichwald												a			a			a
Inoceramus eximius Eichwald																		
Inoceramus cf. I. lucifer Eichwald	a		a	a	a	a		a										
Inoceramus porrectus Eichwald?																		
Inoceramus																		
Avicula			a	a											a		a	a
Pteria (large, strongly sculptured)																		
Pteria																		

	2997	10516	10518	2996	10517	10519	2995	2993	2994	10515	10514, 10523	10513, 7466	7467 (2)	10511	10512	7465	10245	7467 (12a)
Cladophlebis																		
Marattiopsis or Danaeopsis																		
Sagenopteris göppertiana Zigno									b			b	b					
Sagenopteris göppertiana?																		b
Sagenopteris																		
Sagenopteris?																b		
Macrotaeniopteris californica Fontaine									b									
Nilsonia orientalis Heer																		
Nilsonia																		
Pterophyllum rajmahalense Morris									b				b					
Pterophyllum rajmahalense?																		
Pterophyllum or Zamites																		
Fieldenia nordenskiöldi Nathorst?																		
Fieldenia?												b						
Pagiophyllum?																		
Phoenicopsis?																		
Stem (coniferous)																		
Stems													b			b		
Fossil wood																		
Serpula																		
Rhynchonella						a					a							
Terebratula (large broad form)																		
Terebratula																		
Grammatodon									a					a			a	
Grammatodon? sp. a																		
Grammatodon? sp. b																		
Grammatodon?																		
Cucullaea								a										
Cucullaea??																		
Arca																		
Arca?														a				
Pinna (more slender than P. expansa and with longitudinal striae)									a									
Pinna				a	a									a			a	
Gervillia (large species)																		
Inoceramus ambiguus Eichwald			a				a	a				a		a	a		a	
Inoceramus eximius Eichwald																		
Inoceramus cf. I. lucifer Eichwald																		
Inoceramus porrectus Eichwald?																		
Inoceramus																		
Avicula							a		a									
Pteria (large, strongly sculptured)																		
Pteria														a				

	7468	7469	7440	10522	12074	3014	3015	2992	3050	3049	11014	11020	10980	11019	11021	10979	10998
Cladophlebis			b														
Marattiopsis or Danaeopsis																	
Sagenopteris göppertiana Zigno			b														
Sagenopteris göppertiana?	b																
Sagenopteris																	
Sagenopteris?		b															
Macrotaeniopteris californica Fontaine			b														
Nilsonia orientalis Heer			b														
Nilsonia																	
Pterophyllum rajmahalense Morris																	
Pterophyllum rajmahalense?																	
Pterophyllum or Zamites																	
Fieldenia nordenskiöldi Nathorst?			b														
Fieldenia?																	
Pagiophyllum?			b														
Phoenicopsis?																	
Stem (coniferous)																	
Stems																	
Fossil wood																	
Serpula																	
Rhynchonella																	
Terebratula (large broad form)																	
Terebratula																	
Grammatodon				a				a									
Grammatodon? sp. a																	
Grammatodon? sp. b																	
Grammatodon?																	
Cucullaea																	
Cucullaea??																	
Arca																	
Arca?																	
Pinna (more slender than P. expansa and with longitudinal striae)																	
Pinna																	
Gervillia (large species)																	
Inoceramus ambiguus Eichwald				a	a	a	a	a	a								
Inoceramus eximius Eichwald								a									
Inoceramus cf. I. lucifer Eichwald																	
Inoceramus porrectus Eichwald?																	
Inoceramus												a		a			a
Avicula																	
Pteria (large, strongly sculptured)																	
Pteria																	

Pteria?																																																					
Eumicrotis cf. E. curta Hall									a	a		a	a																																								
Eumicrotis											a																								a																		
Eumicrotis?																																														a	a						a
Ostrea (simple ovate form)																										a																											
Ostrea (very large species)																																																					
Ostrea (small irregular species)																																																					
Ostrea	a			a																													a														a						
Ostrea?																																																					
Exogyra																																																					
Trigonia devexa Eichwald																																																					
Trigonia doroschini Eichwald																																																					
Trigonia sp. 3																		a				a			a																												
Trigonia sp. c, cf. T. dawsoni Whiteaves																										a	a					a	a		a																		
Trigonia sp. d, (clavellatae resembling sp. c but larger)										a			a																																								
Trigonia (large clavellatae)																																																					
Trigonia (clavellatae)											a																																										
Trigonia sp. e (undulatae)										a																																											
Trigonia (undulatae)	a										a																																										
Trigonia (very large form)		a																																																			
Trigonia																																																					
Pecten sp. a																										a																											
Pecten (large smooth form)	a			a														a																																			
Pecten (smooth form)		a																									a													a		a										a	
Pecten (small smooth form)																																																					
Pecten (large coarse-ribbed form)		a																																																			
Pecten (large form with coarse complex structure)																																																					
Pecten										a						a	a																a		a									a									
Pecten (small ribbed form)																																																					
Camptonectes																																																					
Lima cf. L. gigantea Sowerby	a							a										a																																			
Lima (medium-sized, smooth form)															a																																						
Lima																																	a																				
Anomia																																																					
Modiola													a																																								
Pleuromya sp. a							a											a	a			a				a	a					a	a																				
Pleuromya sp. b																		a	a			a				a	a					a	a																				
Pleuromya sp. c																														a																							
Pleuromya (short, broad form)																																																					
Pleuromya (different from sp. a and b)													a																																								
Pleuromya	a		a	a						a					a										a				a						a					a			a	a	a	a					a		a
Pleuromya?													a																																								
Pholadomya					a	a																																																
Goniomya	a																									a	a																										
Anatina?																																																					
Thracia																																			a																		
Thracia?													a																																								
Arctica																																																					
Arctica? (large form)																																																					

• a, Identified by T. W. Stanton; b, identified by F. H. Knowlton.

Fossils from Tuxedni sandstone of Cook Inlet—Continued

	3010	3012	3011	3009	3008	3006	3007	3005	3003	3002	10521	3001	3004	3013	3000	10520	2998	2999	2997	10516	10518	2996	10517	10519	2995	2993	2994	10515	10514, 10523	10513, 7466	7467 (2)	10511	10512	7465	10245	7467 (12a)	7468	7469	7440	10522	12074	3014	3015	2992	3050	3049	11014	11020	10980	11019	11021	10979	10998
Cyprina? (large oval form)													a																																								
Cyprina? (large shell with anterior and posterior lateral teeth)																																											a										
Cyprina? (large sp.)																																																					
Cyprina?	a																															a																					
Praeconia?																																	a																				
Astarte sp. a (large, nearly smooth, crenulated margin)																											a																										
Astarte sp. b (small)																											a																										
Astarte (small, coarse ribbed form)										a			a																																								
Astarte (large)	a																																																				
Astarte (small)	a																																																				
Astarte				a																					a										a					a													
Astarte?											a																																										
Tancredia?													a																																	a							
Lucina	a																																																				
Sphaeriola?																																	a																				
Protocardia	a						a				a		a	a				a																	a																		
Protocardia?																																	a																				
Isocardia?																																																					
Undetermined Veneridae	a																a	a																																			
Quenstedtia?																																																					
Undetermined Solenidae?	a																																																				
Dentalium?																																															a						
Pleurotomaria															a																																						
Turbo?																																												a									
Amberleya																	a																																				
Amberleya?	a																																																				
Natica	a																																																				
Turritella?																																								a													
Cerithium	a																	a																	a																		
Alaria?	a																																																				
Aporrhais?																																								a													
Actaeon?										a																																											
Gastropod																																																					
Phylloceras							a								a			a								a		a												a			a										
Phylloceras? (large, with coarse sculpture)																																											a										
Phylloceras? (young specimen)	a																																									a											
Haploceras?																																	a																				
Lytoceras															a																																						
Oppelia?															a			a																																			

Sonninia? (large, smooth form)				a																																																	
Sonninia? (smaller form with strong sculpture)				a																																																	
Sonninia? (small form with strong sculpture)	a			a																																																	
Sonninia? (another sculptured form)	a																																																				
Sonninia?															a			a																																			
Harpoceras																																																					
Harpoceras? (Sonninia) (small keeled form with coarse ribs)													a																																								
Harpoceras?					a																																																
Stephanoceras cf. S. humphriesianum (Sowerby)	a													a				a							a																												
Stephanoceras richardsoni Whiteaves																																																					
Stephanoceras richardsoni Whiteaves?																												a																									
Stephanoceras sp. a															a		a	a																																			
Stephanoceras sp. b																	a	a																																			
Stephanoceras																a																			a																		
Stephanoceras? cf. Ammonites asterianus D'Orbigny and A. loganianus Whiteaves																																									a		a	a									
Stephanoceras? (robust form with small umbilicus)				a																																																	
Stephanoceras? (more compressed form with larger umbilicus)				a																																																	
Stephanoceras?																																																					
Stephanoceras? cf. Perisphinctes carlottensis Whiteaves																		a																														a					
Stephanoceras? (or Perisphinctes)															a			a	a																																		
Sphaeroceras cf. Olcostephanus oblatum Whiteaves																	a					a			a							a	a																				
Sphaeroceras cf. Olcostephanus cepoides Whiteaves															a			a	a	a												a																					
Sphaeroceras? sp. a																										a																											
Sphaeroceras sp. b																											a																										
Sphaeroceras																		a						a				a	a				a		a					a		a											
Sphaeroceras?																																																					
Macrocephalites																																																					
Macrocephalites?																																																					
Perisphinctes cf. P. carlottensis (Whiteaves)															a		a													a																							
Perisphinctes																								a					a	a			a																				
Perisphinctes (small form with bifurcating ribs)	a																																																				
Parkinsonia? cf. P. parkinsoni Sowerby																																																					
Ammonite																																																			a		
Belemnites sp. a																																																					
Belemnites sp. b																																																					
Belemnites sp. c																																																					
Belemnites (slender form)																																																					
Belemnites (hastate form)																																																					
Belemnites	a	a	a		a					a	a				a	a		a				a		a	a		a		a			a			a					a			a	a		a							

Fossils from Tuxedni sandstone of Cook Inlet—Continued

	10999	11000	11063	11033, 7520	10981	11022	11023-11029	11030	11031	11032	11034	11035	11036	11037	11038, 7521	11039	7522	11040	11041	10983, 7527	10984	11042	11043	7523	11044	11045	10985
Cladophlebis																											
Marattiopsis or Danaeopsis																											
Sagenopteris göppertiana Zigno																											
Sagenopteris göppertiana?																											
Sagenopteris															b												
Sagenopteris?																											
Macrotaeniopteris californica Fontaine																											
Nilsonia orientalis Heer																											
Nilsonia															b												
Pterophyllum rajmahalense Morris																											
Pterophyllum rajmahalense?																											
Pterophyllum or Zamites				b																							
Fieldenia nordenskiöldi Nathorst?																											
Fieldenia?																											
Pagiophyllum?																											
Phoenicopsis?																	b							b			
Stem (coniferous)																				b							
Stems																											
Fossil wood																											
Serpula																											
Rhynchonella			a													a											
Terebratula (large broad form)																											
Terebratula																a											
Grammatodon															a			a	a			a					
Grammatodon? sp. a																											
Grammatodon? sp. b																											
Grammatodon?																						a					
Cucullaea																											
Cucullaea?																											
Arca																											
Arca?																											
Pinna (more slender than P. expansa and with longitudinal striae)																											
Pinna							a																				
Gervillia (large species)																											
Inoceramus ambiguus Eichwald	a														a			a		a	a						
Inoceramus eximius Eichwald																											
Inoceramus cf. I. lucifer Eichwald																											
Inoceramus porrectus Eichwald?													a														
Inoceramus																			a								
Avicula																											
Pteria (large, strongly sculptured)																a											
Pteria																											

	11046	11047	7524	11048	11051	10987	11053	10993	7528	7526	3040	3038	3037	3039	3036	2919	3035	11062	11061	3034	3033	3032	2920	11057	3027	12101
Cladophlebis																										
Marattiopsis or Danaeopsis									b	b																
Sagenopteris göppertiana Zigno																						b				
Sagenopteris göppertiana?																									b	
Sagenopteris			b																							
Sagenopteris?																										
Macrotaeniopteris californica Fontaine																										
Nilsonia orientalis Heer																										
Nilsonia																										
Pterophyllum rajmahalense Morris																										
Pterophyllum rajmahalense?																										
Pterophyllum or Zamites																										
Fieldenia nordenskiöldi Nathorst?																										
Fieldenia?																										
Pagiophyllum?																										
Phoenicopsis?																										
Stem (coniferous)																										
Stems																										
Fossil wood																										
Serpula																										
Rhynchonella																						a				
Terebratula (large broad form)																										
Terebratula		a																								
Grammatodon		a																			a	a			a	
Grammatodon? sp. a																a							a			
Grammatodon? sp. b																							a			
Grammatodon?																										a
Cucullaea																										
Cucullaea?																	a									
Arca																										
Arca?																										
Pinna (more slender than P. expansa and with longitudinal striae)																										
Pinna		a																								
Gervillia (large species)																										
Inoceramus ambiguus Eichwald	a	a			a	a						a		a								a			a	a
Inoceramus eximius Eichwald																							a			
Inoceramus cf. I. lucifer Eichwald																					a					
Inoceramus porrectus Eichwald?																										
Inoceramus																										
Avicula																										
Pteria (large, strongly sculptured)																										
Pteria																			a							

Pteria?																a						a																															
Eumicrotis cf. E. curta Hall																																																					
Eumicrotis																																																					
Eumicrotis?		a		a					a	a												a																a	a			a	a					a					
Ostrea (simple ovate form)																																																					
Ostrea (very large species)																																										a											
Ostrea (small irregular species)																																											a							a			
Ostrea																																																a					
Ostrea?												a																																									
Exogyra																																																				a	
Trigonia devexa Eichwald																											a												a														
Trigonia doroschini Eichwald																																			a				a			a	a	a			a						
Trigonia sp. 3																																																					
Trigonia sp. c, cf. T. dawsoni Whiteaves																																																					
Trigonia sp. d (clavellatae resembling sp. c but larger)																																									a								a				
Trigonia (large clavellatae)																																															a	a					
Trigonia (clavellatae)																																											a										
Trigonia sp. e (undulatae)																																																					
Trigonia (undulatae)																																																a					
Trigonia (very large form)																																																					
Trigonia													a			a									a																					a					a		a
Pecten sp. a																																																					
Pecten (large smooth form)																																																					
Pecten (smooth form)																a		a																														a					
Pecten (small smooth form)																																							a				a							a			
Pecten (large coarse-ribbed form)																																																					
Pecten (large form with coarse complex structure)																																									a							a	a				
Pecten															a							a							a																a	a				a		a	
Pecten (small ribbed form)																		a																																			
Camptonectes																a																a																	a				
Lima cf. L. gigantea Sowerby																																																	a				
Lima (medium-sized, smooth form)																																																					
Lima																						a							a																								
Anomia														a																																							
Modiola																																																					
Pleuromya sp. a																																																					
Pleuromya sp. b																																																					
Pleuromya sp. c																																																					
Pleuromya (short, broad form)																											a																										
Pleuromya (different from sp. a and b)																																																					
Pleuromya				a											a			a		a									a										a		a			a		a		a	a			a	
Pleuromya?																																																					
Pholadomya																																																	a				
Goniomya																																																	a				
Anatina?																																														a							
Thracia															a																												a						a				
Thracia?																																		a												a							
Arctica																																														a							
Arctica? (large form)																																													a								

Fossils from Tuxedni sandstone of Cook Inlet—Continued

	10999	11000	11063	11033, 7520	10981	11022	11023–11029	11030	11031	11032	11034	11035	11036	11037	11038, 7521	11039	7522	11040	11041	10983, 7527	10984	11042	11043	7523	11044	11045	10985
Cyprina? (large oval form)																											
Cyprina? (large shell with anterior and posterior lateral teeth)																											
Cyprina? (large sp.)																											
Cyprina?																											
Praeconia?																											
Astarte sp. a (large, nearly smooth, crenulated margin)																											
Astarte sp. b (small)																											
Astarte (small, coarse ribbed form)																											
Astarte (large)																											
Astarte (small)																											
Astarte																a			a							a	
Astarte?																											
Tancredia?																											
Lucina																											
Sphaeriola?																											
Protocardia																											
Protocardia?																											
Isocardia?															a												
Undetermined Veneridae										a																	
Quenstedtia?																											
Undetermined Solenidae?																											
Dentalium?																											
Pleurotomaria																											
Turbo?																											
Amberleya																											
Amberleya?								a						a	a												
Natica																											
Turritella?																											
Cerithium																						a					
Alaria?																											
Aporrhais?																											
Actaeon?																											
Gastropod																		a									
Phylloceras					a							a				a							a				
Phylloceras? (large, with coarse sculpture)																											
Phylloceras? (young specimen)																											
Haploceras?											a																
Lytoceras																											
Oppelia?																											

	11046	11047	7524	11048	11051	10987	11053	10993	7528	7526	3040	3038	3037	3039	3036	2919	3035	11062	11061	3034	3033	3032	2920	11057	3027	12101
Cyprina? (large oval form)																										
Cyprina? (large shell with anterior and posterior lateral teeth)																										
Cyprina? (large sp.)												a														
Cyprina?																	a					a				
Praeconia?																										
Astarte sp. a (large, nearly smooth, crenulated margin)																										
Astarte sp. b (small)																										
Astarte (small, coarse ribbed form)																										
Astarte (large)												a										a				a
Astarte (small)																										
Astarte														a												
Astarte?																			a							
Tancredia?																					a					
Lucina																										
Sphaeriola?																										
Protocardia												a		a												
Protocardia?																										
Isocardia?																										
Undetermined Veneridae																										
Quenstedtia?																		a	a							
Undetermined Solenidae?																										a
Dentalium?																										
Pleurotomaria																										
Turbo?																										
Amberleya																										
Amberleya?																										
Natica		a																								
Turritella?																										
Cerithium																										
Alaria?																										
Aporrhais?																										
Actaeon?																										
Gastropod																										
Phylloceras		a		a																		a			a	
Phylloceras? (large, with coarse sculpture)																										
Phylloceras? (young specimen)																										
Haploceras?																										
Lytoceras																										
Oppelia?		a		a			a																			

Sonninia? (large, smooth form)																																																					
Sonninia? (smaller form with strong sculpture)																																																					
Sonninia? (small form with strong sculpture)																																																					
Sonninia? (another sculptured form)																																																					
Sonninia?																																																					
Harpoceras												a	a																																								
Harpoceras? (Sonninia) (small keeled form with coarse ribs)																																																					
Harpoceras?																																																						
Stephanoceras cf. S. humphresianum (Sowerby)																																																					
Stephanoceras richardsoni Whiteaves																																																					
Stephanoceras richardsoni Whiteaves?																																																					
Stephanoceras sp. a																																																					
Stephanoceras sp. b																																																					
Stephanoceras																																																		a			
Stephanoceras? cf. Ammonites asterianus D'Orbigny and A. loganianus Whiteaves																																																					
Stephanoceras? (robust form with small umbilicus)																																																					
Stephanoceras? (robust form with small umbilicus)																																																					
Stephanoceras? (more compressed form with larger umbilicus)																																																					
Stephanoceras?											a	a	a																									a	a					a					a				
Stephanoceras? cf. Perisphinctes carlottensis Whiteaves																																																					
Stephanoceras? (or Perisphinctes)																																																					
Sphaeroceras cf. Olcostephanus oblatum Whiteaves					a																																																
Sphaeroceras cf. Olcostephanus cepoides Whiteaves						a																																															
Sphaeroceras? sp. a																																																					
Sphaeroceras sp. b																																																					
Sphaeroceras												a	a									a																										a				a	
Sphaeroceras?							a						a		a																																						
Macrocephalites																													a																								
Macrocephalites?																																a																					
Perisphinctes cf. P. carlottensis (Whiteaves)																																																					
Perisphinctes																																																					
Perisphinctes (small form with bifurcating ribs)																																																					
Parkinsonia? cf. P. parkinsoni Sowerby																																							a														
Ammonite						a																																															
Belemnites sp. a																																																	a			
Belemnites sp. b																																																	a			
Belemnites sp. c																																																	a			
Belemnites (slender form)																																																a			a	
Belemnites (hastate form)																																																a			a	
Belomnites								a							a			a				a							a			a						a	a	a		a										

3010. South shore of Tuxedni Bay. Talus at base of bed 37 of section on p. 143. These probably came from either bed 36 or bed 37 and could not have come from higher than bed 35. T. W. Stanton, 1904.

3012. South shore of Tuxedni Bay. Band of grit 3½ feet thick at top of bed 36. T. W. Stanton, 1904.

3011. South shore of Tuxedni Bay. Lower 10 feet of bed 35. T. W. Stanton, 1904.

3009. South shore of Tuxedni Bay. Bed 33. T. W. Stanton, 1904.

3008. South shore of Tuxedni Bay. Upper part of bed 32. T. W. Stanton, 1904.

3006. South shore of Tuxedni Bay. Bed 31. T. W. Stanton, 1904.

3007. South shore of Tuxedni Bay. Talus from same locality as 3006. T. W. Stanton, 1904.

3005. South shore of Tuxedni Bay. Bed 30. T. W. Stanton, 1904.

3003. South shore of Tuxedni Bay. Base of bed 28. T. W. Stanton, 1904.

3002. South shore of Tuxedni Bay. Bed 25. T. W. Stanton, 1904.

10521 (20 F 11). South shore of Tuxedni Bay. Bed 25. F. H. Moffit, 1920.

3001. South shore of Tuxedni Bay, 3 miles west of Chisik Island. Base of bed 24. T. W. Stanton, 1904.

3004. South shore of Tuxedni Bay. Talus just east of the outcrop of bed 29, probably from a higher horizon than 3001. T. W. Stanton, 1904.

3013. South shore of Tuxedni Bay. Upper member (clay shale) of bed 22. T. W. Stanton, 1904.

3000. South shore of Tuxedni Bay. Concretions in bed 19. T. W. Stanton, 1904.

10520 (20 F 10). South shore of Tuxedni Bay. Bed 18. F. H. Moffit, 1920.

2998. South shore of Tuxedni Bay. Bed 14. T. W. Stanton, 1904.

2999. South shore of Tuxedni Bay. Talus, probably mostly from beds 11 to 14. T. W. Stanton, 1904.

2997. South shore of Tuxedni Bay. Bed 11. T. W. Stanton, 1904.

10516 (20 AI 5). South shore of Tuxedni Bay. Bed 11. Herbert Insley, 1920.

10518 (20 F 6). South shore of Tuxedni Bay. Bed 7 or 8. F. H. Moffit, 1920.

2996. South shore of Tuxedni Bay. Base of bed 7. T. W. Stanton, 1904.

10517 (20 F 5). South shore of Tuxedni Bay. Bed 7. F. H. Moffit, 1920.

10519 (20 F 7, 8, 9). South shore of Tuxedni Bay. Bed 6. F. H. Moffit, 1920.

2995. South shore of Tuxedni Bay. Bed 4. T. W. Stanton, 1904.

2993. South shore of Tuxedni Bay 2 miles west of cabin on Chisik Island. Bed 1. T. W. Stanton, 1904.

2994. South shore of Tuxedni Bay, small gulch about half a mile south of 2993. Probably about same horizon as 2993. T. W. Stanton, 1904.

10515 (20 F 4). South shore of Tuxedni Bay one-fourth mile west of Fossil Point. F. H. Moffit, 1920.

10514, 10523 (20 AI 3, 20 F 3). South shore of Tuxedni Bay 200 feet west of Fossil Point. Moffit and Insley, 1920.

10513, 7466 (20 AI 2, 20 F 2). South shore of Tuxedni Bay just west of extreme end of Fossil Point. Moffit and Insley, 1920.

7467 (20 F 2). South shore of Tuxedni Bay at Fossil Point. F. H. Moffit, 1920.

10511 (20 AI 1). South shore of Tuxedni Bay just southeast of end of Fossil Point. Herbert Insley, 1920.

10512 (20 F 1). South shore of Tuxedni Bay on south side of Fossil Point. F. H. Moffit, 1920.

7465 (20 AI 1, 20 F 1). South shore of Tuxedni Bay just southeast of end of Fossil Point. Moffit and Insley, 1920.

10245 (B). South shore of Tuxedni Bay near Fossil Point. C. N. Fenner, 1919.

7467 (20 F 12 a). South shore of Tuxedni Bay 200 yards south of Fossil Point. F. H. Moffit, 1920.

7468 (20 F 12 b). South shore of Tuxedni Bay 200 yards south of Fossil Point. F. H. Moffit, 1920.

7469 (20 F 12 c). South shore of Tuxedni Bay 200 yards south of Fossil Point. F. H. Moffit, 1920.

7440 (20 F 13 a). West shore of Snug Harbor 5 miles south of Fossil Point. F. H. Moffit, 1920.

10522 (20 F 13 b). West shore of Snug Harbor 5 miles south of Fossil Point. Limy concretions in creek. F. H. Moffit, 1920.

12074 (A) Chisik Island, 5 miles north of cannery. W. R. Smith, 1923.

3014. West shore of Chisik Island 1 mile north of cabin. Concretions in shale beds below a massive conglomerate. T. W. Stanton, 1904.

3015. North end of Chisik Island, about one-fourth mile northeast of 3014; from higher beds. T. W. Stanton, 1904.

2992. West shore of Chisik Island 4,000 to 4,200 feet north of cabin. Shale and calcareous concretions overlying a massive conglomerate. T. W. Stanton, 1904.

3050. South shore of Chinitna Bay 1 mile below head of bay. G. C. Martin, 1904.

3049. South shore of Chinitna Bay 3 miles below head of bay. G. C. Martin, 1904.

11014 (AB F 5). South shore of Chinitna Bay about a mile northwest of mouth of Fitz Creek. Arthur A. Baker, 1921.

11020 (AB F 27). South shore of Chinitna Bay 300 feet north of 11019. Arthur A. Baker, 1921.

10980 (F 3). South shore of Chinitna Bay 800 feet west of 10979. Fred H. Moffit, 1921.

11019 (AB F 26). South shore of Chinitna Bay about 700 feet north of emergence of Tuxedni sandstone from under alluvium. Arthur A. Baker, 1921.

11021 (AB F 28). 100 feet southeast of 11019. Arthur A. Baker, 1921.

10979 (F 2). South shore of Chinitna Bay, most easterly exposure of Tuxedni sandstone on west side of Fitz Creek. Fred H. Moffit, 1921.

10998 (AB F 6). South shore of Chinitna Bay about two-thirds of a mile northwest of Fitz Creek. Arthur A. Baker, 1921.

10999 (AB F 7). Cliffs south of head of Chinitna Bay. Arthur A. Baker, 1921.

11000 (AB F 8). At elevation 250 feet, up creek that drains from topographic station "Sharp" into head of Chinitna Bay. Arthur A. Baker, 1921.

11063 (AB F 80). 3,500 feet up tributary of Fitz Creek from north about 1⅔ miles from Chinitna Bay. Arthur A. Baker, 1921.

11033 (AB F 40). Mountain top 3 miles southwest of mouth of Fitz Creek. Arthur A. Baker, 1921.

7520 (AB F 41). Same locality as 11033. Arthur A. Baker, 1921.

10981 (F 4). East side of Fitz Creek, 3 miles south of Chinitna Bay. Fred H. Moffit, 1921.

11022 (AB F 29). Fitz Creek about 3 miles from Chinitna Bay. Arthur A. Baker, 1921.

11023–11029 (AB F 30–36). Same locality as 11022. Arthur A. Baker, 1921.

11030 (AB F 37). Short distance up tributary to Fitz Creek that drains divide northeast of Tonnie Peak. Arthur A. Baker, 1921.

11031 (AB F 38). About 1,000 feet up same tributary as 11030. Arthur A. Baker, 1921.

11032 (AB F 39). About 1,500 feet up same tributary as 11030. Arthur A. Baker, 1921..

11034 (AB F 42). About 7,200 feet up small creek coming from south into Fitz Creek about 1⅔ miles from Chinitna Bay. Arthur A. Baker, 1921.

11035 (AB F 44). About 9,000 feet up same creek as 11034. Arthur A. Baker, 1921.

11036 (AB F 43). About 8,000 feet up same creek as 11034. Arthur A. Baker, 1921.

11037 (AB F 45). About 3,000 feet up creek that drains into headwaters of Bowser Creek from the south. Arthur A. Baker, 1921.

11038 (AB F 46). About 1,000 feet up creek from 11037. Arthur A. Baker, 1921.

7521 (AB F 46). About 1 mile south from divide between Fitz Creek, Brown Creek, and Bowser Creek; same locality as 11038. Arthur A. Baker, 1921.

11039 (AB F 47). 2,000 feet farther up creek than 11038. Arthur A. Baker, 1921.

7522 (AB F 48). About 8,300 feet up creek from 7521. Arthur A. Baker, 1921.

11040 (AB F 49). 1,120 feet from 11039, on first right fork of left fork. Arthur A. Baker, 1921.

11041 (AB F 50). Crossing over hill to next creek to west at altitude 875 feet. Arthur A. Baker, 1921.

10983 (F 5). Head of Bowser Creek, south side of valley at about elevation 800 feet. Fred H. Moffit, 1921.

7527 (F 5). Bowser Creek, same locality as 10983. Fred H. Moffit, 1921.

10984 (F 6). Head of Bowser Creek, near 10983. Fred H. Moffit, 1921.

11042 (AB F 51). On tributary to Bowser Creek from south about 1,900 feet up creek from trail crossing. Arthur A. Baker, 1921.

11043 (AB F 52). On same tributary as 11042, about 2,300 feet up creek from trail crossing. Arthur A. Baker, 1921.

7523 (AB F 52). About 2½ miles from divide described under 7521. Arthur A. Baker, 1921.

11044 (AB F 53). 3,300 feet up creek from trail crossing at altitude 360 feet (taking east fork at 2,500). Arthur A. Baker, 1921.

11045 (AB F 54). 3,900 feet up creek described under 11042 (taking east fork at 2500), at B 370. Arthur A. Baker, 1921.

10985 (F 7 a and b). Tributary to Bowser Creek from south next below head of stream; 3,800 feet from point where tributary enters Bowser Creek valley. Fred H. Moffit, 1921.

11046 (AB F 55). 4,400 feet up same creek as 11042. Arthur A. Baker, 1921.

11047 (AB F 56). 4,800 feet up same creek as 11042. Arthur A. Baker, 1921.

7524 (AB F 56). About 7,200 feet up same creek as 11042. Arthur A. Baker, 1921.

11048 (AB F 57). 6,540 feet up same creek as 11042, taking west fork at 5550. Arthur A. Baker, 1921.

11051 (AB F 62). 5,400 feet up same creek as 11042. Arthur A. Baker, 1921.

10987 (F 9). Tributary to Bowser Creek from south, next below head branch of stream, three-fourths mile below forks, a little less than 50 feet south of and stratigraphically below F 8. Fred H. Moffit, 1921.

11053 (AB F 64). A short distance above assumed Tuxedni-Chinitna contact along same creek as 11042. Arthur A. Baker, 1921.

10993 (F 15). Northwest side Right Arm of Iniskin Bay, at head of arm. Fred H. Moffit, 1921.

7528 (F 16). Right Arm of Iniskin Bay. Fred H. Moffit, 1921.

7526 (AB F 79). Sandstone on east shore of west arm of Right Arm of Iniskin Bay. Arthur A. Baker, 1921.

3040. East shore of Iniskin Bay 1½ miles above Brown's upper cabin, which is 4 miles above the entrance to the bay. T. W. Stanton, 1904.

3038. East shore of Iniskin Bay about 1 mile above upper cabin, or near point at entrance to east arm of bay. Zone A. T. W. Stanton, 1904.

3037. East shore of Iniskin Bay about half a mile above upper cabin. T. W. Stanton, 1904.

3039. East shore of Iniskin Bay 100 to 400 yards above upper cabin. T. W. Stanton, 1904.

3036. East shore of Iniskin Bay 1½ miles above lower cabin.

2919. East shore of Iniskin Bay. "Zones A and B." Mixed specimens from beds represented by lots 3038 and 3035. G. C. Martin, 1903.

3035. East shore of Iniskin Bay 1¼ miles above lower cabin. "Zone B." T. W. Stanton, 1904.

11062 (AB F 78). East shore of Iniskin Bay 6,500 feet north from end of trail at lower cabin. Arthur A. Baker, 1921.

11061 (AB F 77). East shore of Iniskin Bay 5,400 feet north from end of trail at lower cabin. Arthur A. Baker, 1921.

3034. East shore of Iniskin Bay 1 mile above lower cabin. T. W. Stanton, 1904.

3033. East shore of Iniskin Bay one-fourth to 1 mile above lower cabin. Sixty-five feet of strata above fault. T. W. Stanton, 1904.

3032. East shore of Iniskin Bay 300 yards above lower cabin. About 300 feet of strata. T. W. Stanton, 1904.

2920. East shore of Iniskin Bay near lower cabin. From "Zone C." G. C. Martin, 1903.

11057 (AB F 70). East shore of Iniskin Bay about 250 feet south from end of trail at lower cabin. Arthur A. Baker, 1921.

3027. East shore of Iniskin Bay between lower cabin and next creek below it. Upper part of "Zone C." T. W. Stanton, 1904.

12101. About 2 miles north of Amakdedori, on west shore of Kamishak Bay. K. F. Mather, 1923.

Stanton's opinion[13] regarding the marine fossils is that

The fauna, except possibly a few species of *Belemnites* and pelecypods, is entirely distinct.

No closely similar fauna has been found elsewhere in Alaska or on the American continent, except on the Queen Charlotte Islands, where certain localities in the "Lower Shales" have yielded ammonites and a few other forms that evidently belong to this fauna and have no connection with the Cretaceous fauna from other localities on Queen Charlotte Islands, supposed to be in the same formation. Its exact correlation with European Jurassic faunas must await the exhaustive study and description of the collections, but it certainly includes at least a part of the Lower Oolite or Middle Jurassic.

[13] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 402, 1905.

The opinion stated by Hyatt[14] regarding the fossils from Tuxedni Bay is as follows:

The fossils from Tuxedni Harbor, Chasik Island (No. 1495), are Inferior Oolite. A characteristic species of *Trigonia* is identical with one found in the Mormon sandstone at Taylorville, Calif., which is characteristic in that formation. There is also a well-preserved specimen of Ammonitinae, sufficient in itself to settle the age of this rock. It is a species of *Sphaeroceras*, closely allied if not identical with the Mormon sandstone species and a very close ally of the *Sphaeroceras* (*Stephanoceras*) *giebelii* Gottsche, found in the Inferior Oolite west of Mendoza in Chile. The aperture is well preserved in one specimen, and successful cleaning has exposed the inner whorls, so that no doubt can reasonably be held that this is a representative of the common fossils of this genus in the Inferior Oolite or Europe.

The fossil plants from the Tuxedni sandstone have been discussed by Knowlton,[15] as follows:

The forms that have been specifically named are determined with a great degree of certainty, the most abundant being the *Sagenopteris*, which occurs at five localities. * * * The named species, not to go further afield, are found in the so-called "Jurassic" at Oroville, Calif., but apparently have not been found in the Cape Lisburne region of Alaska, although the *Sagenopteris* is not greatly different from a species that is.

UPPER JURASSIC

CHINITNA SHALE

Historical review.—The rocks now included in the Chinitna shale were first described by Martin[16] as the uppermost member (zone D) of the "Enochkin formation," and the description included detailed stratigraphic sections and lists of fossils identified by T. W. Stanton. The "Enochkin formation" was described in greater detail by Stanton and Martin,[17] who discussed at length its age and correlation and gave stratigraphic sections and lists of fossils. They recognized the possible desirability of subdividing it into two formations, as was subsequently done, when they said:[18]

The Enochkin formation, as defined and described in the preceding pages, might well be divided into two formations, differing somewhat lithologically, and each characterized by a distinct fauna. In the upper two-thirds shales predominate, and the most characteristic fossils are several species of *Cadoceras*. This portion, which we have mentioned as "zone D" or the "*Cado-*

[14] Hyatt, Alpheus, Report on the Mesozoic fossils (appendix to Dall's Report on coal and lignite of Alaska): U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 907–908, 1896.

[15] Knowlton, F. H., cited by Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 64, 1912.

[16] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 38–44, 1905.

[17] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Bull. Geol. Soc. America, vol. 16, pp. 397–402, 1905.

[18] Idem, p. 401.

ceras zone," has been recognized by its fossils from Snug Harbor (Tuxedni Bay) to Cold Bay.

Brief mention of the fauna of the "upper part of the Enochkin formation," which is now known as the Chinitna shale, was made by Stanton[19] in discussing the position of the Jurassic rocks of the Rocky Mountain region. The flora of these beds was also discussed briefly by Knowlton[20] in a consideration of the Jurassic-Cretaceous problem of Oregon and California.

The Chinitna shale was first described as a separate formation by Martin and Katz,[21] who defined it as including the strata formerely referred to "zone D" or the "*Cadoceras* zone" of the "Enochkin formation," the type exposures being on the north shore of Chinitna Bay. This account consists of a compilation of the earlier descriptions and includes detailed stratigraphic sections and lists of fossils identified by Stanton and by Knowlton.

A brief description of the Chinitna shale, summarized from previous descriptions, was given by Martin[22] in an account of the oil fields of Cook Inlet. The occurrence of the Chinitna shale on Tuxedni Bay has been briefly described by Moffit.[23] The exposures of the Chinitna shale and other Jurassic rocks in the peninsula between Chinitna and Iniskin bays were studied in considerable detail by Moffit, and his preliminary report on these studies[24] contains a discussion of the character, distribution, thickness, structure, and age of the formation.

A possible occurrence of the Chinitna shale on the west shore of Kamishak Bay has been described briefly by Mather.[25]

Stratigraphic description.—The Tuxedni sandstone is overlain, probably conformably, by the basal Upper Jurassic formation of the Cook Inlet section, which has been named the Chinitna shale. This formation has a thickness of at least 1,300 feet, and probably 2,400 feet, and consists of a conformable and fairly uniform succession of fine-grained marine sediments, mostly shale.

The limits of the formation are somewhat in doubt. The contact with the underlying formation has nowhere been clearly ob-

[19] Stanton, T. W., Succession and distribution of later Mesozoic invertebrate faunas in North America: Jour. Geology, vol. 17, pp. 411–412, 1909.

[20] Knowlton, F. H., The Jurassic age of the "Jurassic flora of Oregon": Am. Jour. Sci., 4th ser., vol. 30, pp. 49–50, 1910.

[21] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 65–68, pl. 2, 1912.

[22] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 43–48, pl. 8, 1921.

[23] Moffit, F. H., Geology of the vicinity of Tuxedni Bay, Cook Inlet: U. S. Geol. Survey Bull. 722, pp. 142, 144, pl. 2, 1922.

[24] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, pp. 122–123, pl. 3, 1922.

[25] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, p. 168, 1925.

served. The base of the formation is not exposed in the type section in Chinitna Bay, and the contact with the underlying formation of Iniskin Bay is possibly along a fault. The exposures at the type locality on the north shore of Chinitna Bay include, above the characteristic fossiliferous beds of this formation, other apparently nonfossiliferous beds of somewhat similar lithologic character, which aggregate at least 1,200 feet in thickness. These in turn are overlain by the characteristic Upper Jurassic strata of the Naknek formation. These nonfossiliferous strata have been tentatively assigned to the Chinitna shale but should not be regarded as constituting an essential part of its type section. The Chinitna shale, as originally defined and as now regarded by the writer, is the exact equivalent of "zone D" or the "*Cadoceras* zone" of the "Enochkin formation." It should include the strata characterized by *Cadoceras* and its associates and should exclude the higher *Aucella* and *Cardioceras*-bearing beds. The apparently barren zone between the *Cadoceras*-bearing beds and the *Aucella* and *Cardioceras*-bearing beds at Chinitna Bay can not be assigned to a definite position on the basis of the facts now available. If in the future fossils are found in that zone, the contained strata may be referred to the Chinitna shale, the Naknek formation, or a new intermediate formation, according as the relationships of the fauna indicate.

Section of part of Chinitna shale on creek half a mile west of high cliffs on north shore of Chinitna Bay

	Feet
1. Dark shale with a few bands of more indurated argillaceous sandstone	425
2. Dark shale with beds of argillaceous sandstone forming many cascades. *Cadoceras* seen near the middle	650
3. Indurated bands of argillaceous sandstone with abundant specimens of *Cadoceras* and *Belemnites* (lot 3018)	10
4. Dark shale and argillaceous sandstone	115
5. Similar beds not well exposed	200
6. Dark shale weathering to brownish slopes, with bands of small concretions containing *Cadoceras doroschini*, etc. (lot 3019), near top	330
7. Similar shale, mostly covered	75
8. Dark clay shale, weathering brownish, with concretions containing *Cadoceras*, etc., near middle	110
	1,915

The exposures recorded in this section, which were measured by T. W. Stanton, extend upward into inaccessible cliffs whose rocks, dipping northeastward, descend into the cliffs on the shore of the bay, where the following section was measured by Stanton. The uppermost beds of the preceding section consist of dark shale like that of No. 2 in the following section, and beds resembling No. 1 of

the following section were seen at an estimated distance of 100 feet above. The exposures as viewed from a point across the bay appear, however, to include a considerable thickness of light-colored banded sandstone that was not recognized as such in the preceding section and that may represent a few hundred feet of strata that should be interpolated between the two sections. The following section, which was also measured by T. W. Stanton, immediately underlies the section of strata referred to the Naknek formation as given on pages 172–173.

Section of part of Chinitna shale (?) at west end of cliffs on north shore of Chinitna Bay

	Feet
1. Dark argillaceous sandstone, passing downward into indurated dark shale with conspicuous thin bands and elongated lenses of yellowish impure limestone	475
2. Dark indurated shale	37

It should be noted that no fossils have been found in the upper 750 feet of strata in the creek section given on page 160, or in the lower 690 feet of the cliff sections given on pages 161 and 172–173. This apparently barren interval includes a total of 1,200 feet or more of beds that have been included in the Chinitna shale, as well as the lower 175 feet of the section referred to the Naknek formation. (See p. 173.) The present assignment of these apparently nonfossiliferous strata is based wholly upon the lithologic character of the rocks and is purely tentative.

The following section, measured by the writer in 1903, was the type section[26] for the upper member (zone D) of the "Enochkin formation." It is immediately overlain by the Chisik conglomerate member of the Naknek formation, as described on page 170.

Section of Chinitna shale on east shore of Iniskin Bay

	Feet
1. Dark-drab shale with numerous bands of calcareous concretions filled with well-preserved specimens of *Cadoceras*, *Belemnites*, etc., and with a few sticks of fossilized wood	146
2. Shale as above, partly concealed by talus at Mushroom Rocks; thickness computed	77
3. Dark shale as above, with same concretions, wood, and fossils	190
4. Shale as above, with *Cadoceras*	6
5. Limestone	1
6. Shale as above (large cephalopod collected at base)	68
7. Shale as above	295
8. Shale, partly concealed by talus; thickness computed	300
9. Shale as above	200
10. Concealed	25±
	1,308±

[26] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 41–42, 1905.

The lowest strata in this section are in close proximity to the highest bed of the Tuxedni sandstone, as given in the section on page 145, and appear to overlie that bed. It is possible, however, that a fault is present in the concealed interval.

The fossils of lot 2921 were collected from the positions indicated in beds 1, 3, 4, and 6, and from talus at the base of the cliffs. They were not kept separate, as they seemed to represent a single fauna, and as lack of time prevented the making of exhaustive collections from the individual beds.

This section was reexamined in 1904 by Stanton, who collected *Cadoceras* and other fossils from a bed near the base of the section (3028), from higher beds about three-fourths of a mile farther south (3029), and from the upper 100 feet of bed 1 (3030). Stanton noted, a short distance above the lower *Cadoceras* zone, rocks that resembled the "dark shale with yellowish indurated bands" of the Chinitna Bay section, but states that "the conspicuously banded light-colored sandstones higher up in the section at Chinitna Bay have apparently disappeared or changed their lithologic character." *Cadoceras* occurs most abundantly at Iniskin Bay in the shale and sandstone overlying the "dark shale with yellowish indurated bands" and extending 200 or 300 feet higher (3029). This circumstance points strongly toward the probability of *Cadoceras* occurring considerably higher at Chinitna Bay than it has been recorded and tends to justify the tentative reference of the apparently nonfossiliferous shale of the Chinitna Bay section to this formation.

The following section was measured by the writer in the cliffs on the northeast shore of Oil Bay. The rocks at the base of the section are concealed, the Tuxedni sandstone not being exposed on Oil Bay, and there is considerable doubt as to just what part of the Chinitna shale is represented. The upper bed of the section is directly overlain, apparently conformably, by the rocks referred to the Naknek formation in the section given on page 173.

Section of upper part of Chinitna shale on east shore of Oil Bay

	Feet
1. Dark shale with concretions and with fossils (lot 3041) 46 feet above base	690
2. Hard dark sandstone	½
3. Dark-drab shale with numerous concretions	530
4. Calcareous shale with *Cadoceras schmidti* Pompeckj, *Cadoceras* sp. cf. *C. stenoloboide* Pompeckj, and *Phylloceras* (lot 2941)	1
5. Dark shale with *Cadoceras doroschini*, etc. (lot 3042)	60
6. Soft green sandstone	½
7. Dark-drab shale	12
	1,294

The typical Chinitna fauna, with *Cadoceras*, has been found in only the lower 72 feet of the Oil Bay exposures. Above these beds is a great thickness of strata, including the remainder of this section and the lower 150 feet of the beds referred to the Naknek formation in the section on page 173, in which only a few fossils have been found, and these few do not furnish conclusive evidence as to their age. These beds accordingly, like the nonfossiliferous strata on Chinitna Bay, have been divided between the Chinitna shale and the Naknek formation on the basis of their lithologic character.

The exposures on Chisik Island, which have not been studied in detail, seem to show a section similar to that on Iniskin Bay. A few fossils were found (lot 2990) not far below the base of the Chisik conglomerate, and *Cadoceras* was collected (lot 2991) several hundred feet lower.

The following description by Moffit[27] was based on a detailed study of exposures in the peninsula between Chinitna and Iniskin bays.

The Chinitna shale consists of gray, black, and reddish argillaceous shale, in which are interstratified some sandy and calcareous beds and rare beds of grit. This formation is of fairly homogeneous character and differs from the prevailing shales of the upper part of the Tuxedni sandstone in that it is argillaceous rather than arenaceous, yet the shales of both formations at their contact are similar in appearance and composition and are distinguished from each other on paleontologic and not on lithologic evidence. Lines of fossiliferous concretions indicating the bedding planes are numerous in the lower part of the formation, and in most places where exposures are good they make it possible to determine within narrow limits the boundary line between this and the underlying formation. The upper part of the Chinitna shale, on the other hand, yields few fossils, yet it is characterized by discontinuous thin calcareous beds which are shaped like much elongated lenses and have a conspicuous yellowish color where weathered. These yellowish bands, although present throughout the upper 500 feet of the shale, give much assistance in determining the position of the formation boundary.

The Chinitna shale occupies the intermediate slopes of the landward side of the coast mountains, overlying the Tuxedni sandstone of the foothills and lower slopes and underlying the Chisik conglomerate and Naknek formation, which form the brow and crest of the ridge. It thus appears on the map as a narrow band nowhere more than a mile wide.

The thickness of the Chinitna shale in its type locality, as measured by Stanton, is 2,315 feet, and that of the partial sections on Iniskin and Oil bays is 1,308 feet and 1,294 feet, respectively. The base of the shale is not included in either of these partial sections, yet the thickness represented by them is nearer the thickness of some other sections between Iniskin and Chinitna bays than that of the type section. A section at the head of Bowser Creek gives 1,425 feet as the thickness of the Chinitna shale at this locality. . .

Age and correlation.—The fossils obtained from the Chinitna shale are listed in the accompanying table.

[27] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, p. 123, 1922.

Fossils from Chinitna shale of Cook Inlet [a]

	2991	2990	3016	12050	3020	3019	3018	10978	11010	10994	10996	10997	11003	11004	11005	11007	11008	11009	11011	11012	7519	10982	11041	10986	11049	11050	11052	11052a	3042	2941	3041	11054	3028	3029	3030	2921	10989	10990	10991	10992	11058	11059	7525	11060
Cladophlebis denticulata (Brongniart) Seward																																	b											
Dictyophyllum cf. D. obtusilobum																																	b											
Hausmannia sp.? (mere fragment)																																	b											
Ctenis grandifolia Fontaine																																	b											
Nilsonia cf. N. orientalis Heer																																											b	
Phoenicopsis speciosa Heer																					b																							
Plant fragments															a			a																										
Fossil wood																																		b										
Serpula?																																				a								
Bryozoa?									a																																			
Rhynchonella																a																												
Leda?																				a																								
Grammatodon																	a			a												a	a	a										
Inoceramus	a										a																																	
Avicula																																	a											
Pteria																																a												
Trigonia																																					a					a		
Pecten (small smooth form)				a																																a								
Pecten (smooth form)														a																														
Pecten																													a		a	a	a	a								a		
Lima																																				a								
Modiola?																																		a										
Pleuromya				a							a																		a												a			a
Pleuromya?																																				a								
Pholadomya																																		a										
Goniomya																																		a		a								
Thracia																				a														a										a
Astarte																a																		a								a		
Lucina?										a																																		
Venerid?																				a																								
Tellina?																a																												
Pelecypod burrows																				a																								
Dentalium		a																																										
Turbo																															a													
Amberleya																																a												
Cerithium																																	a											

Gastropod									a																																			
Phylloceras subobtusiforme Pompeckj?																																				a								
Phylloceras		a										a														a				a			a	a										
Phylloceras?																			a																									
Oxynotoceras?																																	a	a										
Oxynotoceras? (smooth, sharp-centered form)					a																																							
Harpoceras?																																							a					
Stephanoceras cf. Ammonites asterianus (Eichwald)																																				a								
Kepplerites? cf. K. loganianus (Whiteaves)																																								a				
Sphaeroceras																																	a	a										
Sphaeroceras?																							a																					
Macrocephalites																									a																			
Macrocephalites?																																				a								
Cadoceras catostoma Pompeckj?																																				a								
Cadoceras doroschini (Eichwald)				a		a																a	a		a	a	a		a				a	a		a	a							
Cadoceras doroschini (Eichwald)?	a				a		a						a																						a									
Cadoceras grewingki Pompeckj																																												a
Cadoceras schmidti Pompeckj																														a						a								
Cadoceras stenoloboide Pompeckj	a																						a															a						
Cadoceras stenoloboide Pompeckj?			a					a																				a		a														
Cadoceras wosnessenskii (Grewingk)																																				a								
Cadoceras (less convex than C. doroshini)						a																																						
Cadoceras (compressed ribbed form)							a																																					
Cadoceras																								a					a				a	a	a	a								
Cadoceras?																																	a									a		
Cadoceras?? (smooth, close-coiled form)						a																																						
Cadoceras? (globose with narrow umbilicus)																						a																						
Cosmoceras?																																							a					
Belemnites (very large phragmacone)					a																														a									
Belemnites	a			a			a																a						a			a		a		a								
Crustacean												a																																

[a] a, Identified by T. W. Stanton; b, identified by F. H Knowlton.

2991. West shore of Chisik Island, several hundred feet below top of Chinitna shale. T. W. Stanton, 1904.

2990. West shore of Chisik Island, near top of Chinitna shale. T. W. Stanton, 1904.

3016. Northeast shore of Chisik Island, near top of Chinitna shale. T. W. Stanton, 1904.

12050 (G). Chisik Island. "Limestone above heavy conglomerate." C. N. Fenner, 1919.

3020. North shore of Chinitna Bay about 125 feet above sea level, on first small creek west of the high cliffs. T. W. Stanton, 1904.

3019. North shore of Chinitna Bay about 270 feet above sea level, on first small creek west of the high cliffs. Near top of bed 6 of section on p. 160. T. W. Stanton, 1904.

3018. North shore of Chinitna Bay about 410 feet above sea level, on first small creek west of the high cliffs. Bed 3. T. W. Stanton, 1904.

10978 (F 1). South side of entrance to Chinitna Bay, 700 feet west of point 2½ miles east of Camp Point. F. H. Moffit, 1921.

11010 (AB F 18). South shore of Chinitna Bay. Upper middle part of Chinitna shale. A. A. Baker, 1921.

10994 (AB F 1). South shore of Chinitna Bay. Upper member of Chinitna shale. A. A. Baker, 1921.

10996 (AB F 3). South shore of Chinitna Bay. Upper member of Chinitna shale. A. A. Baker, 1921.

10997 (AB F 4). South shore of Chinitna Bay. Top member of Chinitna shale. A. A. Baker, 1921.

11003 (AB F 10). South shore of Chinitna Bay. Top member of Chinitna shale. A. A. Baker, 1921.

11004 (AB F 12). South shore of Chinitna Bay. Talus probably near top of Chinitna shale. A. A. Baker, 1921.

11005 (AB F 13). South shore of Chinitna Bay. A. A. Baker, 1921.

11007 (AB F 15). South shore of Chinitna Bay. Talus probably near top of Chinitna shale. A. A. Baker, 1921.

11008 (AB F 16). South shore of Chinitna Bay. Upper part of Chinitna shale. A. A. Baker, 1921.

11009 (AB F 17). South Shore of Chinita Bay. A. A. Baker, 1921.

11011 (AB F 19). South shore of Chinitna Bay. Upper part of Chinitna shale. A. A. Baker, 1921.

11012 (AB F 20). South shore of Chinitna Bay. Upper part of Chinitna shale. A. A. Baker, 1921.

7519 (AB F 2). South shore of Chinitna Bay. A. A. Baker, 1921.

10982 (F 4 a) Head of Bowser Creek, south side of valley, at about elevation 1,000 feet above sea level. F. H. Moffit, 1921.

11041 (AB F 50). Crossing over hill to next creek to west, at altitude 875 feet. A. A. Baker, 1921.

10986 (F 8). Tributary to Bowser Creek from south, next below head branch of stream; three-fourths mile below forks of stream at locality 507. F. H. Moffit, 1921.

11049 (AB F 58). Chinitna shale, 8,080 feet up same creek as 10986. A. A. Baker, 1921.

11050 (AB F 59 and 60). 8,400 feet up creek leading to peak east of C Y Peak. A. A. Baker, 1921.

11052 (AB F 63). Chinitna shale about 9,000 feet up creek. A. A. Baker, 1921.

11052a (AB F 68). East shore of Oil Bay at northeast corner. A. A. Baker, 1921.

3042. Northeast shore of Oil Bay. Lower 50 feet of section. T. W. Stanton, 1904.

2941. Northeast shore of Oil Bay. Bed 4 of section on p. 162. G. C. Martin, 1903.

3041. Northeast shore of Oil Bay near large waterfall. Forty-six feet above base of bed 1 of section. T. W. Stanton, 1904.

11054 (AB F 65). West shore of Oil Bay about 600 feet from Bowser Creek. A. A. Baker, 1921.

3028. East shore of Iniskin Bay one-fourth mile below lower cabin. "Zone D." T. W. Stanton, 1904.

3029. East shore of Iniskin Bay 1 mile below lower cabin. Three hundred feet or more above 3028. T. W. Stanton, 1904.

3030. East shore of Iniskin Bay 1¼ miles below lower cabin. Upper 100 feet of Chinitna shale. T. W. Stanton, 1904.

2921. East shore of Iniskin Bay. Upper 1,200 feet of Chinitna shale. G. C. Martin, 1903.

10989 (F 11). East shore of Iniskin Bay south of trail to Oil Bay. F. H. Moffit, 1921.

10990. East shore of Iniskin Bay 1 mile south of trail to Oil Bay. F. H. Moffit, 1921.

10991. East shore of Iniskin Bay 1 mile south of trail to Oil Bay. Float. F. H. Moffit, 1921.

10992 (F 14). East shore of Iniskin Bay 1 mile south of trail to Oil Bay. F. H. Moffit, 1921.

11058 (AB F 72). East shore of Iniskin Bay 4,700 feet below end of trail at lower cabin. A. A. Baker, 1921.

11059 (AB F 73 and 75). East shore of Iniskin Bay 6,100 feet south from end of trail at lower cabin. A. A. Baker, 1921.

7525 (AB F 74). East shore of Iniskin Bay about 6,050 feet south from end of trail at lower cabin. A. A. Baker, 1921.

11060 (AB F 76). East shore of Iniskin Bay 8,200 feet down shore from lower cabin, or about 750 feet below Toadstool Islands. Just below contact with Chisik conglomerate. A. A. Baker, 1921.

The fauna includes abundant cephalopods and a few other marine mollusks. The most abundant and characteristic members of the fauna are ammonites, especially the several species of *Cadoceras*, which are characteristic of the Callovian of Europe and of other northern regions. A meager fossil flora is associated with the marine mollusks at several localities.

The following discussion[28] of the fauna of the Chinitna shale was written by Stanton:

Its characteristic ammonites have been assigned to the Callovian by Neumayr, Hyatt, and Pompeckj, all of whom recognized the character of the fauna, which is represented by closely similar forms in Russia, Franz Josef Land, and elsewhere in northern regions, as well as in other parts of Europe. This Callovian fauna is placed by many geologists in the lower part of the

[28] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 17, p. 401, 1905.

Upper Jurassic, but it seems to accord better with the local development in Alaska to follow the custom of some German geologists and assign it to the top of the Middle Jurassic. Seven species of *Cadoceras* have been named from Alaska, some of which will evidently become synonyms when the large collections now on hand are fully studied, and possibly one or two additional names will be necessary. With these are associated *Sphaeroceras*, *Phylloceras*, and one or two other genera of ammonites, belemnites, and a very few pelecypods and gastropods.

The flora of the Chinitna shale was described by Knowlton,[29] as follows:

The forms that have been specifically named are determined with a great degree of certainty. * * * The two remaining forms are mere fragments that will not admit of specific identification, though there can be absolutely no doubt as to the correctness of the generic reference, especially that of the *Dictyophyllum*, which seems to be in fruit. As to the distribution of the named species, the *Cladophlebis* occurs in the Jurassic of England and France as well as other parts of the Old World and, moreover, is very close to what has been called "*Asplenium*" *whitbiense*, which occurs abundantly in the Jurassic of eastern Siberia and California. The other named species, not to go farther afield, are found in the "so-called" Jurassic at Oroville, Calif., but apparently have not been found in the Cape Lisburne region of Alaska.

NAKNEK FORMATION

Historical review.—The Naknek formation, the typical occurrence of which is on the Alaska Peninsula and is described on pages 203–218, is also well developed on the west coast of Cook Inlet. The occurrence of the Naknek formation in this district was first indicated by Martin,[30] who gave only a brief and general description. The Naknek formation of Cook Inlet was described in detail by Stanton and Martin.[31] This account includes stratigraphic sections and a general discussion of the character and relations of the fauna. The fauna of the Naknek formation of Cook Inlet was discussed briefly by Stanton [32] in an account of the Jurassic beds of the Rocky Mountain region. The occurrence, character, and relations of the Naknek formation on that part of the west coast of Cook Inlet lying north of Iniskin Bay were described by Martin and Katz,[33] whose account comprises the detailed stratigraphic sections and the discussion of age and correlation substantially as given by Stanton and Martin but includes some additional data on the petrographic character of the tuffaceous beds and a more complete discussion of the correla-

[29] Knowlton, F. H., cited by Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, p. 64, 1912.

[30] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 43–45, 1905.

[31] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 402–407, 1905.

[32] Stanton, T. W., Succession and distribution of later Mesozoic invertebrate faunas in North America: Jour. Geology, vol. 17, pp. 411–412, 414, 1909.

[33] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 69–74, pl. 2, 1912.

tion of these beds with the Jurassic rocks of other Alaskan districts. The occurrence of these rocks is also represented on a geologic map and in structure sections.

An account of the oil fields of Cook Inlet by Martin contains a description of the Naknek formation[34] that includes a general discussion and local details of the exposures north of Iniskin Bay compiled from the publication just mentioned, together with descriptions of the exposures south of Iniskin Bay not previously published.

The specimens of *Cardioceras* collected by Stanton from the lower part of the Naknek formation on the east shore of Oil Bay have been described by Reeside,[35] who gave systematic descriptions of the species, most of which were new, together with a discussion of the age of the beds, which he correlated with the Sundance formation of Wyoming and with the Argovian or Lower Oxfordian of most European stratigraphers.

The Naknek formation of the vicinity of Tuxedni Bay was described briefly by Moffit,[36] who stated that the formation includes a lower part composed chiefly of shale, with some sandstone, arkose, tuff, and conglomerate, and an upper part composed of massive light-colored sandstone. These two divisions are mapped separately.

The Naknek formation of the peninsula between Chinitna and Iniskin Bays was described by Moffit[37] as including a lower division, 1,500 feet thick, composed of gray shale with sandstone beds, and an upper division, 3,000 feet thick, composed of massive light-colored sandstone, arkose, and tuff. These divisions are mapped separately.

The exposures of the Naknek formation on the west shore of Kamishak Bay have been described briefly by Mather.[38]

The Chisik conglomerate was first described by Martin[39] as Upper Jurassic "agglomerate." It was described by Stanton and Martin[40] as a local lens of coarse agglomerate constituting the basal part of the Naknek formation. The Chisik conglomerate was first given a name by Martin and Katz,[41] who described it briefly as a distinct formation, and discussed its probable relations to the rocks of

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[34] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 43–50, pl. 8, 1921.

[35] Reeside, J. B., jr., Some American Jurassic ammonites of the genera *Quenstedticeras*, *Cardioceras*, and *Amoeboceras*, family Cardioceratidae: U. S. Geol. Survey Prof. Paper 118, 64 pp., 1919.

[36] Moffit, F. H., Geology of the vicinity of Tuxedni Bay, Cook Inlet: U. S. Geol. Survey Bull. 722, pp. 142, 145, pl. 2, 1922.

[37] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, pp. 119–120, 125–126, pl. 3, 1922.

[38] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, pp. 169–171, 1925.

[39] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, p. 44, 1905.

[40] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 406, 1905.

[41] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 68–69, pl. 2, 1912.

this and other Alaskan districts. Martin[42] also gave a brief general description, compiled from the above-mentioned accounts, in a discussion of the oil fields of Cook Inlet.

The type section was studied in 1920 by Moffit,[43] who gave a brief description of the conglomerate. Moffit has also made a detailed study of the exposures in the peninsula between Chinitna and Tuxedni bays, on which a preliminary report[44] has been issued.

The occurrence of a conglomerate on the west shore of Kamishak Bay, which is believed to represent Chisik conglomerate, has been described by Mather.[45]

Stratigraphic description.—The Naknek formation of the west coast of Cook Inlet consists of sandstone, shale, arkose, conglomerate, andesitic tuff, and probably some interbedded andesitic lava, aggregating a thickness of more than 5,000 feet, conformably underlain by a massive conglomerate 300 to 400 feet thick. In previous reports this massive conglomerate has been treated as a distinct formation, but it has recently been considered best by the United States Geological Survey to classify it as a local basal member of the Naknek formation.

The Chisik conglomerate is a massive plate of coarse conglomerate that consists of boulders of granite or diorite and other igneous rocks embedded in a tuffaceous andesitic matrix. It occurs locally in the Upper Jurassic strata of Cook Inlet. At the type locality, on Chisik Island, its maximum observed thickness is 300 to 400 feet; on the east shore of Iniskin Bay its thickness is about 290 feet. The Chisik conglomerate lies with structural conformity on the *Cadoceras*-bearing beds of the Chinitna shale and is overlain conformably by the coarse sandy *Aucella*-bearing beds of the Naknek formation.

On Moffit's geologic map of the peninsula between Chinitna and Iniskin Bays the Chisik conglomerate is represented as a narrow band extending only part way between Iniskin and Oil Bays, for the beds resting on the Chinitna shale on both sides of Oil Bay are made up of grit or fine conglomerate and arkosic sandstone and bear no resemblance to the beds occupying this position on Iniskin Bay. In all other places from Oil Bay to Chinitna Bay, where the base of the Naknek formation was examined by Moffit, the beds in this position consist of coarse arkose and fine grit. It therefore appears that the Chisik conglomerate of Iniskin Bay is probably a local phase of the basal Naknek if its local development and variation in thickness are

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[42] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 43–48, pl. 8, 1921.

[43] Moffit, F. H., Geology of the vicinity of Tuxedni Bay, Cook Inlet: U. S. Geol. Survey Bull. 722, pp. 144–145, pl. 2, 1922.

[44] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, pp. 124–125, pl. 3, 1922.

[45] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, pp. 168–169, 1925.

due to original conditions of deposition, but these irregularities may possibly be due to an unrecognized overlying unconformity. No fossils have been seen in the Chisik conglomerate except possibly uncharacteristic species of *Belemnites*. Its exact age is consequently somewhat in doubt, but its approximate age is clearly shown by its position between the Chinitna shale and the *Cardioceras* zone of the Naknek formation, both of which are Upper Jurassic.

Where the Chisik conglomerate is absent the overlying beds of the Naknek rest, with apparent conformity, upon the nonfossiliferous shale referred tentatively on pages 160–161 to the upper part of the Chinitna shale. The original top of the Naknek formation has not been observed on Cook Inlet, the Cretaceous being lacking and the next younger beds being Tertiary and overlying the Naknek formation unconformably.

The following account by Moffit[46] was based on exposures in the peninsula between Chinitna and Iniskin Bays, but it is descriptive of the formation as exposed all along the west coast of Cook Inlet.

In the area between Chinitna and Iniskin Bays the lower part of the formation, ranging from about 1,500 to 1,645 feet in thickness, consists of gray shale with dark arkosic beds and fine conglomerate or grit at the base and thin sandy beds scattered through it. The overlying sediments are white or light-colored sandstones containing an abundance of igneous material, in part tuff, in part clastic material derived from granite or granite-like rocks, and in part intrusive sills. This upper part includes the remainder of the formation as exposed in the district. These rocks are confined to a curving belt from 2 to 4 miles in width and extend along the whole seaward side of the peninsula from Iniskin Bay to Chinitna Bay.

The basal arkosic beds are also made up of material from a land mass where granite or granitic rocks supplied an abundance of waste for the formation of new sediments and are believed to be the time equivalent of the Chisik conglomerate of Iniskin Bay, for no conglomerate comparable to the Chisik conglomerate of Iniskin Bay was seen elsewhere in the district. The thickness of the coarse-grained basal beds is 147 feet on the east shore of Oil Bay and is approximately the same in other places where the beds were examined. Sandy shales with beds of sandstone succeed the basal beds and together with them make up the lower part of the Naknek formation below the light-colored cliff-forming beds. This part of the Naknek reaches a thickness of 1,645 feet in the section measured by Martin at Oil Bay.

The upper part of the Naknek formation is conspicuous wherever it crops out because of its light color and because it resists erosion better than the underlying beds. It forms the dip slope on the seaward face of the mountains along the coast. Its scarp makes the white cliffs along most of the crest of the mountains as seen from the landward side. This part of the Naknek formation reaches a thickness of at least 3,000 feet. The beds are prevailingly hard and massive but in large exposures show distinctly the bedding lines. They include hard arkosic sandstone, andesitic tuff, coarse and fine sandstone, shale, and conglomerate. Thin sills of quartz diorite are intruded into the sedimentary beds and are distinguished from them only on close examination.

[46] Moffit, F. H., The Iniskin Bay district: U. S. Geol. Survey Bull. 739, pp. 125–126, 1922.

The Naknek beds above the Chisik conglomerate as exposed on Chisik Island include several hundred feet of sparsely fossiliferous calcareous shale that yielded the fossils of lot 3017 (p. 177). This shale is overlain by massive sandstone and tuff that are regarded as also constituting part of the Naknek formation.

The rocks of the Naknek formation exposed on Chinitna Bay are very thick, as shown in the following section, which was measured in the cliffs that border the north shore of the bay for a distance of about 4 miles west from the mouth of East Glacier Creek.

Section of Naknek formation on north shore of Chinitna Bay[47]

	Feet
1 (1–19). Conglomerate and tuff, with some shale and sandstone; *Belemnites* 18 feet above base	113
2 (20–21). Shale with *Aucella* (lot 3022) at top	18
3 (22–37). Conglomerate and tuff with some shale and sandstone	84
4 (38). Shale	25
5 (39). Concealed	462
6 (40–46). Lava and tuff with large concealed intervals	160
7 (47–52). Tuff or lava with some interbedded agglomerate and shale	192
8 (53). Concealed	182
9 (54–60). Tuff and agglomerate with some shale	473
10 (61). Concealed	24
11 (62–64). Shale and sandstone with some interbedded tuff or lava; a few *Belemnites*	123
12 (65). Concealed	338
13 (66–75). Coarse gray sandstone with some shale and fine conglomerate	344
14 (76). Fault (displacement probably small).	
15 (77–82). Coarse gray sandstone with bands of fine conconglomerate and some shale	120
16 (83). Dark shale with *Belemnites*	40
17 (84–87). Sandstone and shale	310
18 (88). Concealed except two or three small outcrops of shaly sandstone	425
19 (89). Dark shale with *Belemnites*	160
20 (90). Coarse cross-bedded sandstone	30
21 (91). Dark shale and shaly sandstone with *Aucella*, etc. (lot 3026)	290
22 (92). Alternating bands of coarse gray and argillaceous fossiliferous sandstone (lot 3025)	100
23 (93–95). Thin-bedded argillaceous sandstone in irregularly alternating light and dark bands, with coarser gray sandstone at top and bottom	388
24 (96–97). Banded sandstone with *Belemnites*	340
25 (98–99). Sandstone and conglomerate	91

[47] Condensed from more detailed section given in Geol. Soc. America Bull., vol. 16, pp. 403–405, 1905, and in U. S. Geol. Survey Bull. 485, pp. 69–71, 1912. The numbers in parentheses are those designating the beds in the detailed section.

	Feet
26 (100). Banded argillaceous sandstone with fossiliferous beds 30 feet (lot 3024) and 25 (75?) feet (lot 3023) above base	156
27 (101). Somewhat massive dark-gray argillaceous sandstone with a few thin yellowish bands	150
	5,138

The section on the east shore of Oil Bay, which is given below, was measured by T. W. Stanton and differs somewhat from the more roughly measured and less carefully studied section measured by Martin.[48] This section is of importance in showing the relative positions of the *Aucella* and *Cardioceras* zones. The light-colored sandstone of No. 8 bears a strong lithologic resemblance to the banded beds of the cliffs on Chinitna Bay. The conglomeratic beds (9 to 16) have been interpreted by Martin[48] as possibly a phase of the Chisik conglomerate, which is otherwise not present on Oil Bay.

Section of Naknek formation on east shore of Oil Bay

	Feet
1. Andesite, interbedded with shale and other sediments	1,400±
2. Dark shale and shaly sandstone with a few thin beds of dark volcanic ash; *Aucella* near base (lot 3047)	600
3. Dark shale and shaly sandstone, as above, with crustacean remains 160 feet above base	480
4. Coarse grit	3
5. Shale and sandstone	25
6. Coarse grit	3
7. Dark shale and shaly sandstone, as above, with *Cardioceras*, etc., 80 feet (lot 3045) and 150 feet (lot 3046) above base	190
8. Irregularly bedded and banded, light-colored, more or less shaly sandstone with fossils 15 feet (lot 3043) and (in talus) 170 feet (lot 3044) above base	362
9. Fine conglomerate, like No. 4	7
10. Thin-bedded shaly sandstone	37
11. Coarse gray grit	1
12. Gray shaly sandstone	34
13. Conglomerate, like No. 4	3
14. Shaly sandstone with *Pleuromya*, *Ammonites*, etc	1
15. Gray conglomerate, somewhat coarser than the underlying bed	8
16. Coarse gray grit or fine conglomerate with many small angular white pebbles one-eighth inch in diameter and some shaly bands toward the top	34
17. Fine gray sandstone with fragmentary bivalves	12
	3,200

[48] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, p. 43, 1905.

On the east shore of Iniskin Bay the Chisik conglomerate member is overlain by 300 feet or more of sandy shale with *Aucella* and *Belemnites* (lot 3031), above which is light-colored thin-bedded sandstone which resembles those of the section in the cliffs on Chinitna Bay and which apparently does not contain fossils. The shale and sandstone aggregate about 580 feet in thickness. These strata are overlain near the mouth of the bay by massive beds of coarse conglomerate and lava or tuff, of which a thickness of 270 feet is exposed on the shore of Iniskin Bay. Higher beds of the same general character form the cliffs outside the entrance to the bay.

A small area of Upper Jurassic rocks forms the bold headland at the north entrance to Ursus Cove. These rocks consist of an undetermined thickness of sandstone with *Aucella* and other fossils (lot 3087). Neither the top nor the bottom of the formation is here exposed, the Jurassic strata being in contact with Triassic rocks that are overthrust upon them.

The Naknek formation is exposed on the foreland south of Ursus Cove. The outcrops on a small indentation of the coast known as Rocky Bay consist of about 75 feet of dark-gray shaly sandstone and sandy shale, resembling those of beds 2 to 7 of the Oil Bay section (p. 173) and containing *Aucella* and other fossils (lot 3090). Higher strata are exposed along the coast farther south, there being an estimated thickness of possibly 800 feet of strata overlying these beds between Rocky Bay and the fault contact with the Triassic rocks just north of Bruin Bay.

The exposures on the cape at the south entrance to Bruin Bay and in the cliffs for about 5 miles south of this point consist of nearly horizontal dark-gray sandstones and sandy shale having a thickness of at least 500 feet. Neither the top nor the bottom of the formation is exposed, the contact with the adjacent Triassic rocks being a fault. *Aucella* and other fossils (lot 9032) were collected near the entrance to Bruin Bay.

The Naknek formation crops out almost continuously in the cliffs on the south shore of Kamishak Bay for about 10 miles west of the mouth of Douglas River. The exposures consist of nearly horizontal beds of buff and gray sandstone, and some of the beds carry numerous fossils, *Aucella* being especially abundant. A very striking but apparently not stratigraphically significant unconformity was observed near the mouth of Douglas River. The character and relations of the beds at this unconformity are shown in the following section, which was measured by T. W. Stanton:

Section of part of Naknek formation on south shore of Kamishak Bay, near mouth of Douglas River

	Feet
1. Gray sandstone; many fossils (lot 3096) in lower part	50
2. Unconformity.	
3. Brownish-yellow cross-bedded sandstone, mostly very friable and barren of fossils. Lignitized wood, *Tancredia*, etc. (lot 3097), near top, and *Modiola*, etc. (lot 3098), 25 feet above base	100
4. Gray sandstone, with some masses weathered yellowish brown. *Aucella*, etc. (lot 3099), 70 feet above base, and *Tancredia*, etc. (lot 3100), 50 feet above base	75

The total thickness of the Naknek formation along this part of the coast was not determined. The top and bottom of the formation and its contacts with other formations were not observed. The beds are in most places nearly horizontal and undulate gently, so that only a slight thickness is exposed at the base of the cliffs. Similar horizontal beds appear to extend inland up to an altitude of 800 or 1,000 feet, there forming the hilltops.

Age and correlation.—The fauna of the post-Chisik beds of the Naknek formation of the west coast of Cook Inlet, as now known, is represented in the following table. It includes 60 or more species of marine mollusks, most of which are undetermined and many of which are probably undescribed. The most significant members of this fauna are the species of *Aucella*, *Lytoceras*, *Phylloceras*, and *Cardioceras*, of which those belonging to the first three genera are characteristic of the formation. According to Stanton,[49]

> The fauna of the Naknek formation is especially characterized by the presence of *Aucella* belonging to species very closely related if not identical with *A. pallasi* and *A. bronni* of the Russian Volga beds. These fossils are at some localities very abundant, completely filling thick beds. At other places they are so rare that they may be easily overlooked, but a careful search will find them in almost every section. Associated with the *Aucella* there are usually two or three species of *Belemnites*, frequently a large *Lytoceras* and a *Phylloceras*, and occasionally a few gastropods, *Trigonia*, and other pelecypods.

Aucella has been found about 1,100 feet above the base and 100 feet below the top of the thick section on Chinitna Bay (pp. 172–173), in the upper 2,500 feet of the section on Oil Bay, at many localities in the beds exposed on Kamishak Bay that seem to represent the upper part of the formation, and apparently in the lowermost 300 or 400 feet of the sections on Chisik Island and Iniskin Bay.

Cardioceras has been found only in the beds exposed on Oil Bay and is there apparently restricted to the lower 700 feet of the section described on page 173. Regarding this genus Stanton [49] said:

[49] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 407, 1905.

At Oil Bay the lower part of the formation yielded two species of *Cardioceras* related to *C. alternans* and *C. cordatus*, which aid greatly in making more definite correlations with both American and European horizons.

The relation of the beds containing *Cardioceras* to those containing *Aucella* at Oil Bay is so clear, and the absence of *Cardioceras* in the *Aucella*-bearing beds, not only at this locality but at all the other localities, is so striking, that it is practically certain that *Cardioceras* can not be regarded as characteristic of the whole formation. In this connection it should be noted that *Cardioceras* has been found at only one locality in the type area of the Naknek formation on the Alaska Peninsula (see pp. 211–212) and has not been found in any of the other Alaskan areas where the supposed equivalents of the Naknek formation are believed to occur, except at a single locality in the Matanuska Valley, described on page 232.

The following is Stanton's opinion[50] regarding the equivalence of the Naknek fauna:

It is clear that the Naknek formation is of about the same age as the Mariposa beds of California with *Aucella erringtoni* and *Cardioceras* cf. *C. alternans*, and it also includes the horizon of the marine Jurassic with *Cardioceras cordiforme* in the Black Hills, where, however, the *Aucella* element is lacking from the fauna, and probably only the horizon of the basal portion of the Naknek is represented. A similar fauna occurs in Russia in the Volgian beds, and it is widespread in the boreal region, occurring on Spitzbergen, Nova Zembla, and elsewhere.

The following statement was made by Reeside:[51]

The four species of *Cardioceras* and one variety from the lower part of the Naknek formation warrant the correlation of the zone containing them with the Sundance and with the *Cardioceras* zone of British Columbia. As the overlying part of the Naknek formation contains *Aucella*, it probably is equivalent, at least in part, to the Mariposa slate and the *Aucella* zone of British Columbia.

Concerning the stratigraphic position of the Sundance formation, Reeside[52] said:

The close relationship between the cardioceratids of the Sundance and those of the zone of *Cardioceras cordatum* Sowerby, of the European Jurassic, indicates their equivalence. It is true that some of the American species seem to have no close relatives in the European faunas, so far as one may judge from the literature of the subject, but the remaining species are sufficient to establish the correlation. Many European stratigraphers refer the *cordatum* zone to the Lower Oxfordian, others to the Upper Oxfordian or to the Lower Corallian, and still others drop the terms Oxfordian and Corallian and substitute Argovian or Sequanian.

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[50] Stanton, T. W., and Martin, G. C., op. cit., p. 407.

[51] Reeside, J. B., jr., Some American Jurassic ammonites of the genera *Quenstedticeras*, *Cardioceras*, and *Amoeboceras*, family Cardioceratidae: U. S. Geol. Survey Prof. Paper 118, p. 11, 1919.

[52] Idem, p. 10.

Fossils from post-Chisik beds of the Naknek formation of Cook Inlet [a]

	3017	3048	3021	3024	3023	3025	3026	3022	10995	11001	11002	11006	11013	11015	11016	11017	11018	11050a	2942	3041	3043	3044	3045	3046	3047	11056	10988	11055	3031	3087	3090	3092	3093	3095	3100	3099	3098	3097	3096	Lower member	Upper member
Plant fragments													a															a												×	
Leda																															a										×
Grammatodon															a																									×	×
Cucullaea?																																a									×
Arca						a																																		×	
Pinna					a																							a												×	
Inoceramus																a															a									×	×
Avicula			a	a		a		a															a																	×	×
Avicula (coarsely ribbed form)																															a	a									×
Pteria															a	a	a																							×	
Eumicrotis?					a																																			×	
Eumicrotis? (large, coarsely striated)																																		a					a		×
Aucella cf. A. erringtoni Gabb								a																					a												×
Aucella (striated)																																a	a	a					a		×
Aucella	a						a																		a					a	a					a					×
Trigonia cf. T. doroschini Eichwald																																		a							×
Pecten					a	a		a																																×	×
Pecten (small smooth form)																																	a								×
Pecten (large smooth form)																																		a							×
Pecten?															a	a																								×	
Modiola (small form)																																			a		a				×
Pleuromya			a	a	a							a			a	a					a			a	a			a												×	×
Pleuromya?																																a									×
Goniomya			a							a		a									a																			×	
Thracia																						a						a												×	
Thracia?									a						a																a									×	×
Arctica?												a															a	a												×	
Cyprina?					a																																			×	
Praeconia?																																		a							×
Astarte					a											a							a																	×	
Astarte (large form)		a																														a							a	×	×
Astarte (large, not crenulated)																																		a		a					×
Astarte distans (Whitfield)																																			a						×
Tancredia (short stout form)																																		a					a		×
Tancredia? (more compressed form)																																							a		×
Tancredia																																			a	a		a			×
Corbula?				a												a																								×	
Panopaea?																																							a		×

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside.

Fossils from post-Chisik beds of the Naknek formation of Cook Inlet—Continued

	3017	3048	3021	3024	3023	3025	3026	3022	10995	11001	11002	11006	11013	11015	11016	11017	11018	11050a	2942	3041	3043	3044	3045	3046	3047	11056	10988	11055	3031	3087	3090	3092	3093	3095	3100	3099	3098	3097	3096	Lower member	Upper member
Pelecypods									a																															×	
Dentalium																														a		a									×
Turbo?																															a										×
Amberleya?																														a											×
Indeterminate gastropods (very small)			a	a					a																														a	×	
Phylloceras (fine sculpture)																														a	a										×
Phylloceras				a	a		a		a							a	a			a			a			a		a												×	×
Phylloceras? (coarse sculpture)																															a	a								×	×
Phylloceras? (young)										a																														×	
Lytoceras (large form)																					a													a					a	×	×
Lytoceras																									a						a									×	×
Cardioceras alaskense Reeside														a						b																				×	
Cardioceras (large smooth form)													a										b																	×	
Cardioceras aff. C. distans (Whitfield																a										a														×	
Cardioceras distans var. depressum Reeside																							b																	×	
Cardioceras hyatti Reeside														a	a																									×	
Cardioceras lillooetense Reeside											a					a																								×	
Cardioceras martini Reeside											a					a						b					a	a												×	
Cardioceras spiniferum Reeside																								b																×	
Cardioceras n. sp.																		a																						×	
Belemnites					a		a	a													a								a											×	×
Belemnites (slender)																														a	a	a									×
Belemnites (large robust)																															a	a							a		×
Crustacean																			a																					×	

3017. West shore of Chisik Island, 1 mile north of south end of island. Shale overlying Chisik conglomerate member and beneath higher lava beds. T. W. Stanton, 1904.

3048. North shore of Chinitna Bay, near head of small creek. T. W. Stanton, 1904.

3021. North shore of Chinitna Bay, at west end of cliffs. Talus. T. W. Stanton, 1904.

3024. North shore of Chinitna Bay. 30 feet above base of bed 26 in section on p. 173. T. W. Stanton, 1904.

3023. North shore of Chinitna Bay. 25 (75?) feet above base of bed 26. T. W. Stanton, 1904.

3025. North shore of Chinitna Bay. Bed 92. T. W. Stanton, 1904.

3026. North shore of Chinitna Bay. Bed 91. T. W. Stanton, 1904.

3022. North shore of Chinitna Bay one-fourth mile west of mouth of East Glacier Creek. Bed 20. T. W. Stanton, 1904.

10995 (AB F 2). South shore of Chinitna Bay. Lower part of Naknek about 200 feet above assumed base. Arthur A. Baker, 1921.

11001 (AB F 9). South shore of Chinitna Bay. Talus, probably in lower part of Naknek. Arthur A. Baker, 1921.

11002 (AB F 11). South shore of Chinitna Bay. Talus, probably in lower part of Naknek. Arthur A. Baker, 1921.

11006 (AB F 14). South shore of Chinitna Bay. Talus, probably in lower part of Naknek. Arthur A. Baker, 1921.

11013 (AB F 21). South shore of Chinitna Bay. Lower part of Naknek. Arthur A. Baker, 1921.

11015 (AB F 22). South shore of Chinitna Bay. Lower part of Naknek. Arthur A. Baker, 1921.

11016 (AB F 23). South shore of Chinitna Bay. Lower part of Naknek. Arthur A. Baker, 1921.

11017 (AB F 24). South shore of Chinitna Bay. Lower part of Naknek. Arthur A. Baker, 1921.

11018 (AB F 25). South shore of Chinitna Bay. Lower part of Naknek. Arthur A. Baker, 1921.

11050a (AB F 61). Near headwaters of tributary entering Bowser Creek from east 2 miles above its mouth. Talus below Chinitna-Naknek contact at same locality as AB F 60. Arthur A. Baker, 1921.

2942. East shore of Oil Bay. Shale near base of Naknek formation (?). (See U. S. Geol. Survey Bull. 485, p. 72, 1912.) G. C. Martin, 1903.

3041. Northeast shore of Oil Bay. Sandstone fragments found at foot of cliff near large waterfall, but derived from a much higher bed. T. W. Stanton, 1904.

3043. Northeast shore of Oil Bay. Stratum 15 feet above base of bed 8 of section on p. 173. T. W. Stanton, 1904.

3044. Northeast shore of Oil Bay. Talus at outcrop of strata 170 feet above base of bed 8. T. W. Stanton, 1904.

3045. Northeast shore of Oil Bay. 80 feet above base of bed 7. T. W. Stanton, 1904.

3046. Northeast shore of Oil Bay. 150 feet above base of bed 7. T. W. Stanton, 1904.

3047. Northeast shore of Oil Bay. Near base of bed 2. T. W. Stanton, 1904.

11056 (AB F 69). East coast of Oil Bay N. 61° E. of Mount Pomeroy. Arthur A. Baker, 1921.

10988 (F 10). West side of Oil Bay, about half a mile from head. Fred H. Moffit, 1921.

11055 (AB F 66 and 67). At second point down Oil Bay from gravel pit near Bowser Creek. Near contact of Chinitna shale and Chisik conglomerate member. Arthur A. Baker, 1921.

3031. East shore of Iniskin Bay, in first cove near entrance to bay. Shales overlying Chisik conglomerate. T. W. Stanton, 1904.

3087. Point at north entrance to Ursus Cove. Sandstone resembling part of beds 2 to 7 of the Oil Bay section. T. W. Stanton, 1904.

3090. Rocky Bay, 8 miles southwest of Ursus Cove. Shaly sandstone and sandy shale, about 75 feet thick, resembling those of beds 2 to 7 of the Oil Bay section. T. W. Stanton, 1904.

3092. South shore of Bruin Bay, bluffs near entrance. Dark-gray sandstone and sandy shale. T. W. Stanton, 1904.

3093. South shore of Kamishak Bay 1 mile east of entrance to "Lower Bear Bay." Gray sandstone. T. W. Stanton, 1904.

3095. South shore of Kamishak Bay 8 or 9 miles southeast of entrance to "Lower Bear Bay" and not over 2 miles west of mouth of Douglas River. Dark-gray sandstone overlying a massive light-buff sandstone. T. W. Stanton, 1904.

3100. South shore of Kamishak Bay near mouth of Douglas River. 50 feet above base of bed 4 of section on p. 175. T. W. Stanton, 1904.

3099. South shore of Kamishak Bay near mouth of Douglas River. 70 feet above base of bed 4. T. W. Stanton, 1904.

3098. South shore of Kamishak Bay near mouth of Douglas River. 25 feet above base of bed 3. T. W. Stanton, 1904.

3097. South shore of Kamishak Bay near mouth of Douglas River. Near top of bed 3. T. W. Stanton, 1904.

3096. West bank of Douglas River 1 mile above mouth. Lower part of bed 1 of section on p. 175, above unconformity. T. W. Stanton, 1904.

The localities in the preceding table are arranged geographically from north to south. The lower member of the post-Chisik rocks that have been referred to the Naknek formation on Cook Inlet, which constitutes the lower Naknek of Moffit and the *Cardioceras* zone as described in this volume, yielded the fossils of lots 3048?, 3021(?), 3023, 3024, 3025, 10995 to 11050a, 2942, 3041 to 3046, 11056, 10988, and 11055. The upper member of the Naknek formation of Cook Inlet, which constitutes the upper Naknek of Moffit, yielded lots 3017, 3026, 3022, 3047, 3031, and 3087 to 3096.

ALASKA PENINSULA

GENERAL FEATURES

The Jurassic rocks of Alaska Peninsula include the direct southwestward extension of the Jurassic rocks on Cook Inlet and constitute a section which, when fully known, will probably be found to rival if not excel the section of Cook Inlet in thickness and completeness. Most of the formations and faunal zones at Cook Inlet are now known on Alaska Peninsula, which contains also some Lower or Middle Jurassic strata that are but little known and that are apparently absent on Cook Inlet. The contact of the Jurassic with the Cretaceous rocks is also exposed on the Alaska Peninsula but not on Cook Inlet. The general section of the Jurassic rocks on Alaska Peninsula is as follows, according to Capps,[55] who also represented it as in Figure 6.

Generalized section of the sedimentary rocks of the Cold Bay district

	Feet
Upper Jurassic:	
Naknek formation (conglomerate and arkosic sandstone from 1,000 to 3,000 feet thick, overlain by sandy shale)	5,000+
Shelikof formation (700 to 1,000 feet of black shale, with some limestone lenses at top, overlying a thick series of sandstone, with minor amounts of conglomerate and sandy to calcareous shale; carries the Chinitna fauna)	5,000–7,000
Unconformity.	
Middle Jurassic: Kialagvik formation (sandstone and sandy shale at Kialagvik Bay)	500+
Lower Jurassic (calcareous sandstone and sandy shale, with limestone at Cold and Alinchak bays)	2,300±
Upper Triassic (thin-bedded limestone and calcareous shale with basaltic dikes and sills at Cape Kekurnoi)	1,000+

[55] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, p. 91, 1922.

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LOWER JURASSIC (?)

Historical review.—Overlying the Upper Triassic rocks near the entrance to Cold Bay is several thousand feet of shale and sandstone that are probably, at least in part, Lower Jurassic.

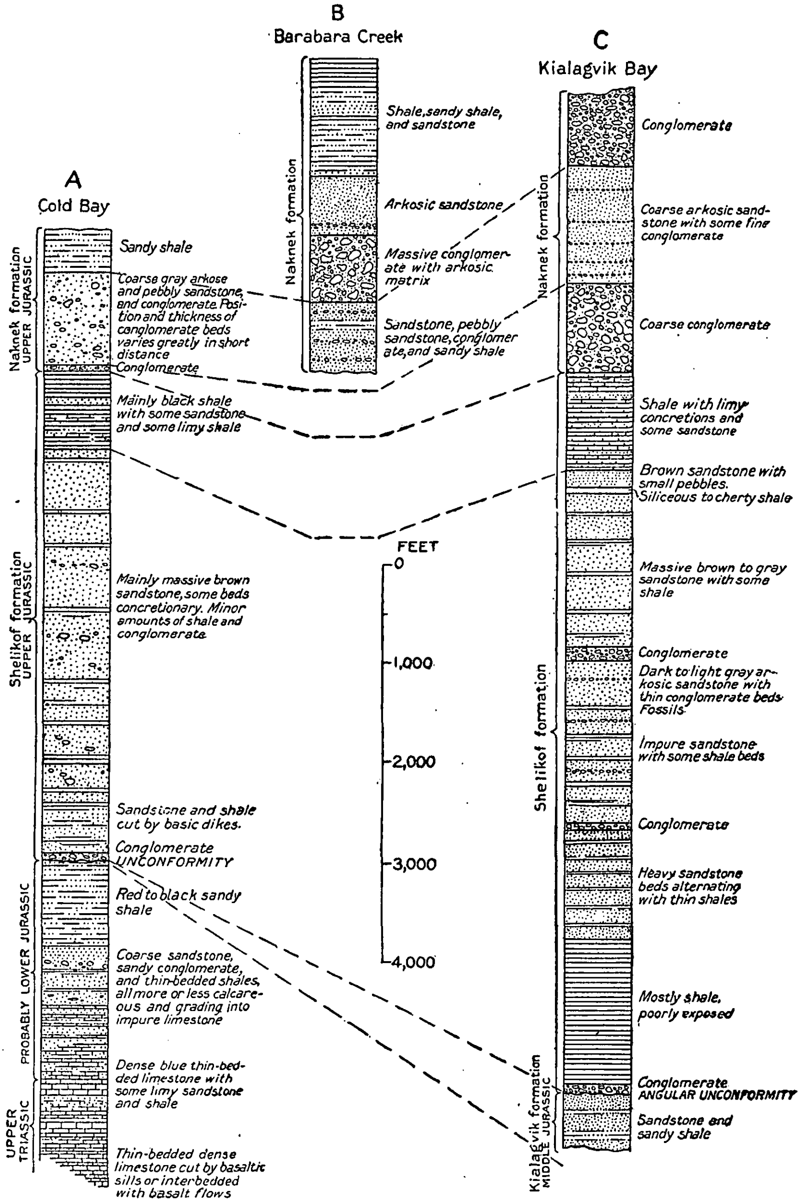

FIGURE 6.—Generalized geologic sections of the Cold Bay district. (After S. B. Capps)

The occurrence of these rocks was mentioned briefly by Stanton and Martin,[56] but no detailed description of their character or

[56] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and the Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 397, 1905.

discussion of their age was given. A brief statement regarding the occurrence was made by Atwood[57] on the basis of the account by Stanton and Martin.

Knowlton's discussion of the Lower Jurassic flora of the Matanuska Valley[58] contains a brief mention of fossil plants from Cold Bay that may be Lower Jurassic. The species in lot 3109 are listed.

A description of the supposed Lower Jurassic of Cold and Alinchak bays was given by Martin[59] in an account of the oil fields of the Alaska Peninsula. The description, which was based on the investigation by Stanton and Martin in 1904, contains a discussion of the character and sequence of the rocks and fossils and consists chiefly of hitherto unpublished information.

An account of the geology of the Cold Bay district by Capps, based on reconnaissance surveys in 1921, contains a description[60] of the character, thickness, and age of the Lower Jurassic rocks of Cold Bay that includes a list by Stanton of some fossils (lot 10820) collected by Capps. The same information was used as the basis of a description of these rocks by Smith and Baker.[61]

Additional information concerning the Lower Jurassic rocks at Cold and Alinchak bays, based on a reconnaissance survey in 1923, has been given by Smith,[62] whose description includes a brief account of the character, sequence, and age of the rocks, with lists of fossils determined by Stanton from material collected by Smith in 1923.

Stratigraphic description.—The Triassic rocks on the northeast shore of Cold Bay (see pp. 61–64) appear to grade upward, with no abrupt change, into less calcareous beds, which do not contain the characteristic Upper Triassic fauna. The change begins about half a mile northwest of Cape Kekurnoi, which is at the eastern entrance to Cold Bay, and the first several hundred feet of strata overlying the known Triassic beds is barren of fossils. Beds of fissile, somewhat calcareous sandstone containing ammonites, pelecypods, and plants (lot 3109; see p. 185) were seen a mile northwest of the cape at a horizon about 700 feet above the highest observed occurrence of Triassic fossils. The general aspect of the ammonites from this locality, according to Stanton, is Jurassic rather than Triassic, but

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[57] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, p. 31, 1911.

[58] Knowlton, F. H., A Lower Jurassic flora from the upper Matanuska Valley, Alaska: U. S. Nat. Mus. Proc., vol. 51, No. 2158, p. 454, 1916.

[59] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 57–60, 1921.

[60] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, 1922, pp. 90, 91, 93–94, pl. 11.

[61] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 169–170, 172–173, pl. 8, 1924.

[62] Smith, W. R., The Cold Bay-Katmai district: U. S. Geol. Survey Bull. 773, pp. 195–196, pl. 4, 1925.

the fossils are unlike any previously known from Alaska. A little farther northwest along the shore, 200 or 300 feet higher, a few more ammonites were collected (lot 3110) and a few specimens of *Rhynchonella* were obtained from a boulder (not in place) on the beach. These ammonites, according to Stanton, include two or three genera of Jurassic aspect and are probably Lower Oolite or older. Another small collection of ammonites and pelecypods (lot 3111) was obtained a short distance south of a large waterfall about 1½ miles northwest of Cape Kekurnoi, about 1,800 feet stratigraphically above the highest beds containing *Pseudomonotis*. There is a sharp change from sandstone to shale at this place, and the dip abruptly changes from 18° to 28°. These changes possibly indicate a fault. The next rocks exposed on the shore northwest of this locality consist of soft brownish shale several hundred feet thick, above which is a heavy bed of coarse conglomerate. The overlying rocks are apparently Upper Jurassic and will be described on page 198.

These Lower Jurassic (?) rocks probably extend northeastward through the hills to Alinchak Bay, where a collection of ammonites (lot 3130) similar to those of lot 3109 has been obtained. The beds that yielded this collection crop out about a quarter of a mile up the shore beyond the Upper Triassic beds containing *Pseudomonotis* (see p. 62) and were not studied in detail. The interval between them and the Triassic exposures is concealed, and the beds that overlie them were not observed.

The Lower Jurassic rocks at Cold Bay, according to Capps,[63]

occur near Cape Kekurnoi in a narrow belt that extends from Cold Bay across the narrow peninsula to Alinchak Bay. The Triassic rocks at the cape, described above, become more sandy and less calcareous northwestward from the highest *Pseudomonotis* zone, although without any observed structural break. The transition from the Triassic limestone and limy shale to impure limestone, calcareous sandstone, and shale is gradual, and it is believed that deposition was here continuous. About 1⅓ miles from the cape a collection of fossils was made that has been determined by T. W. Stanton as probably of Lower Jurassic age.

The sandstone from which this collection was made and some similar conglomerates for some distance above and below the fossiliferous zone are characteristic in that they contain abundant grains of bright-red jasper and brightly colored greenstone particles, with larger fragments of carbonaceous shale.

Of the total thickness of about 2,300 feet of beds here included in the Lower Jurassic, the lower 1,500 feet is prevailingly limestone and limy sandstone and shale at the bottom and prevailingly sandstone at the top. It was in the upper portion that the only fossils were found. Above the portion in which sandstone is dominant there is about 800 feet of beds that consist mainly of black to rusty weathered sandy shales with some thin beds of limestone. It is not certain that these shaly beds belong in the Lower

[63] Capps, S. R., op. cit., pp. 93–94.

Jurassic, but as they seem to lie conformably on the sandstone, they are here tentatively included with the Lower Jurassic. The shales are overlain by a conglomerate 75 feet thick which is believed to mark an unconformity between the Lower Jurassic and the overlying Upper Jurassic beds. It is possible, however, that these shales are to be correlated with the shales in the lower part of the Shelikof formation, as exposed in the Kialagvik Bay section; if so, they are of Upper Jurassic age.

Age and correlation.—The supposed Lower Jurassic shale and sandstone constitute a formation of somewhat problematic age. They apparently overlie the Upper Triassic *Pseudomonotis*-bearing beds conformably and are either overlain by or separated by a fault from strata that carry the Upper Jurassic fauna of the Chinitna shale. It is possible that they may, at least in part, represent the highest Triassic, which elsewhere in Alaska was either not deposited or was removed by subsequent erosion. It is also possible that they may include the off-shore representatives of the Lower Jurassic volcanic beds of Cook Inlet. There are several horizons known in Europe between the Rhaetic and the Oolite that may here be represented.

Fossils from Lower Jurassic (?) shale and sandstone of Cold and Alinchak bays [a]

	3109, 3520	3110	3110a	3111	3111a	3111b	10820	12076	3130	3130a	12075	12082
Sagenopteris											b	
Glossozamites? schrenkii?	b											
Pterophyllum?	b											
Stem												a
Rhynchonella			a				a					
Terebratula							a					
Solemya								a				
Nucula?							a					
Leda	a										a	
Leda?							a					
Gryphaea					a							
Trigonia? (imperfect specimen of Glabrae?)				a				a				
Pecten	a											
Lima cf. L. gigantea Sowerby											a	
Pleuromya?											a	
Undetermined slender bivalve	a											
Pelecypods											a	
Pleurotomaria?							a					
Aegoceras?							a				a	
Phylloceras?											a	
Arietites?							a					
Amaltheus?							a					
Stephanoceras?								a				
Ammonite (coarse-ribbed discoid specimen)	a					a			a			
Ammonite (another coarse-ribbed discoid genus)	a								a			
Ammonite (nearly smooth discoid specimen)	a								a			
Ammonites (two or three other genera of Jurassic aspect)		a									a	
Bone (fragments)										a		

[a] a, Identified by T. W. Stanton; b, identified by F. H. Knowlton.

3109, 3520. Northeast shore of Cold Bay about a mile northwest of Cape Kekurnoi. T. W. Stanton, 1904.

3110. Northeast shore of Cold Bay a short distance northwest of 3109, and 200 or 300 feet higher. T. W. Stanton, 1904.

3110a. Some locality as 3110. Boulder on beach. T. W. Stanton, 1904.

3111. Northeast shore of Cold Bay a short distance south of a large waterfall about 1½ miles northwest of Cape Kekurnoi. T. W. Stanton, 1904.

3111a. Same locality as 3111, but in different matrix. T. W. Stanton, 1904.

3111b. Same locality as 3111, but not in place. T. W. Stanton, 1904.

10820(1–127). North shore of Cold Bay 1⅓ miles northwest of mouth of bay. S. R. Capps, 1921.

12076(2). South shore of Cape Kekurnoi, Cold Bay. W. R. Smith, 1923.

3130. South shore of Alinchak Bay. Lawrence Martin, 1904.

3130a. South shore of Alinchak Bay, near 3130. Not in place. Lawrence Martin, 1904.

12075(1). Southwest shore of Alinchak Bay. W. R. Smith, 1923.

12082(10). West of Alinchak Bay. W. R. Smith, 1923.

Of the fossils included in the earlier collections from these beds, neither the marine mollusks nor the plants are sufficiently characteristic for the determination of the exact horizon. The fossils obtained by Capps in 1921, according to Stanton,[64] include

> several genera of ammonites which in form and sculpture resemble *Arietites*, *Aegoceras*, *Amaltheus*, etc., but which do not show details of sutures and can not be positively identified. This lot is probably from the Lower Jurassic and older than the oldest fauna from Kialagvik Bay.

Concerning the fossils collected by Smith in 1923, Stanton [65] said that lot 12075 " is believed to be Jurassic as old as the Tuxedni sandstone or older " and lot 12076 also "is believed to be Jurassic."

MIDDLE JURASSIC

KIALAGVIK FORMATION

Historical review.—An undescribed Jurassic formation has long been known to be present on Wide Bay (formerly called Kialagvik Bay), where two collections of fossils were made many years ago, but no account of the local stratigraphy has been written until recently. The first fossils brought back from this locality were obtained by a private collector and were described by White,[66] who concluded that "they are certainly of Mesozoic age, and the types to which they belong seem to indicate that they come from a formation of somewhat earlier date than the Cretaceous." After commenting upon the occurrence of *Aucella* at other Alaskan localities, he referred to his previously expressed conclusion [67] that the

[64] Stanton, T. W., cited by Capps, S. R., op. cit., p. 94.

[65] Stanton, T. W., cited by Smith, W. R., op. cit., p. 195.

[66] White, C. A., Mesozoic Mollusca from the southern coast of the Alaskan Peninsula: U. S. Geol. Survey Bull. 51, pp. 64–70, pls. 12–14, 1889.

[67] White, C. A., On a small collection of Mesozoic fossils collected in Alaska by Mr. W. H. Dall, of the United States Coast Survey: U. S. Geol. Survey Bull. 4, p. 11, 1884

Aucella-bearing beds of the Alaska Peninsula are of Neocomian age and said:

> I do not think it impossible that the fossils which form the subject of this article belong to the same formation in Alaska which bears *Aucella concentrica*, but the two types of *Ammonites* which are found among these fossils are at least suggestive of a lower horizon. Indeed, if we had only the type character of the fossils themselves to consider, we should hardly be justified in referring them to a later age than the Jurassic.

White recognized seven species from Wide Bay, as follows:

Cucullaea increbescens, n. sp.
Glycymeris? dalli, n. sp.
Belemnites.
Ammonites (Lillia) howelli n. sp.
Ammonites (Lillia) kialagvikensis, n. sp.
Ammonites (Amaltheus) whiteavesii, n. sp.

White's description of the fossils from Wide Bay has been reviewed by several European geologists, all of whom believe that the ammonites have been referred to wrong genera and that their age can be much more closely determined. E. Haug,[68] in a brief review, states that the fossils are "very probably Liassic" and that the relationships of the ammonites are as follows:

Lillia howelli=Hammatoceras.
Lillia kialagvikensis=Grammoceras near G. toarceuse (D'Orbigny).
Amaltheus whiteavesii=Harpoceras extremely near H. lythense (Young).

A review by Holzapfel[69] expresses the opinion that *Amaltheus whiteavesii* is a *Harpoceras*, and that one of the species referred to *Lillia* is a *Perisphinctes*. Holzapfel believes that the ammonites indicate a horizon corresponding to that of the Volga beds of the Upper Jurassic of Russia, an apparently untenable conclusion in which he was probably influenced by the erroneous belief that these ammonites came from the same beds as the species of *Aucella* from Port Moller that White described in an earlier publication. He was also in error in ascribing to White a belief that the ammonites are Cretaceous. It has been shown above (p. 186) that White believed in 1884 that the species of *Aucella* from Port Moller were Cretaceous, but that in 1889 he concluded the ammonites from Wide Bay are Jurassic. White's further opinion that the Aucellas might possibly belong in the same formation with the Wide Bay fossils (which undoubtedly is not the case) may mean either that he believed the formation to include rocks of both Jurassic and Cretaceous ages, or that he then believed the Aucellas to be Jurassic. The latter conclusion, which is apparently identical with that of Holzapfel, is

[68] Annuaire géologique universal, vol. 8, 1892–93, p. 703.
[69] Neues Jahrb., 1892, Band 2, p. 155.

possibly correct, although the *Aucella*-bearing beds belong at a far higher horizon (pp. 211–218) in the Jurassic than the beds that yielded the ammonites of Wide Bay.

These fossils have also been discussed by Pompeckj,[70] who assigned them to the Upper Liassic and indicated the identity of the ammonites as follows:

> Amaltheus whiteavesii=Harpoceras ex. aff. exarati Young and Bird sp.
> Lillia howelli=Hammatoceras howelli.
> Lillia kialagvikensis=Hammatoceras.

Wide Bay was visited in 1895 by Dall, who collected fossils[71] "at a locality northeast of the mouth of the river which drains a valley up which the natives go to make a portage over to Ugashik Lake." These fossils were studied by Hyatt,[72] who discussed them as follows:

> The Ammonitinae from this locality are excellent but belong to peculiar types, and I have been obliged to make a thorough investigation of the entire series of hammatoceran groups in order to get clear ideas of their exact age. I can now state provisionally that this fauna is somewhat older than that of the lighter-colored limestone of Tuxedni Harbor, Chasik Island. The nearest relatives heretofore found belong to the lowest parts of the Inferior Oolite, in formations placed by many German and French authors in the Upper Lias. There is one species of *Trigonia* identical with a very rare species found at Taylorsville, Calif., in the Mormon sandstone, one of the "*costatus*" group, and the belemnites are also apparently very close allies of those in the same rocks.

The fossils from Wide Bay were briefly referred to by Stanton and Martin,[73] who concluded that "whatever may be the final decision as to their age, they are evidently older than any part of the Enochkin formation."

A brief reference to the occurrence at Wide Bay of the rocks now known as the Kialagvik formation was made by Martin.[74]

The first stratigraphic description of the rocks of the Kialagvik formation was given and the the first use of the formation name made by Capps, who studied the exposures on Wide Bay in 1921. His account of the formation includes a brief description of the character of the rocks followed by lists and a discussion of the fossils by Stanton.[75] The Kialagvik formation was also described by Smith and Baker[76] in a paper based on investigations in 1922.

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[70] Pompeckj, J. F., Jura-Fossilien aus Alaska: K. russ. min. Gesell. St. Petersburg Verh., 2d ser., vol. 38, No. 1, pp. 275–276, 1900.

[71] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 871, 1896.

[72] Hyatt, Alpheus, Report on Mesozoic fossils (appendix to Dall's report on coal and lignite of Alaska. U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 907, 1896.

[73] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 397, 1905.

[74] Martin, G. C., Preliminary report on petroleum in Alaska. U. S. Geol. Survey Bull. 719, pp. 59, 60–61, 1921.

[75] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 91, 94–97, pl. 2, 1922.

[76] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 169, 173–176, pl. 8, 1925.

Stratigraphic description.—The original description, by Capps,[77] of the Kialagvik formation is as follows:

The rocks here named the Kialagvik formation occupy a narrow belt along the northwest shore of Kialagvik [Wide] Bay from a point near the mouth of Pass Creek to the southwest end of the bay. Their extent southwest of the bay is not known. They consist of a few hundred feet of sandstone, sandy shale, and conglomerate that form the bluffs along the beach and extend a short distance inland.

Little is known of the character or thickness of this formation, for the outcrops are scanty and are largely limited to rather widely separated exposures in the shore cliffs, in which massive sandstone, sandy shale, and conglomerate were seen. The exposures are so far from one another that it is not yet possible to construct the stratigraphic section. The contact with the overlying Shelikof formation is in most places concealed on the vegetation-covered benches between the shore and the mountains, but on the shore a short distance east of the mouth of Lee Creek a conglomerate was seen overlying with angular unconformity a series of sandy shales, and this unconformity is believed to mark the contact between the Shelikof formation and the Kialagvik beds.

Age and correlation.—The fossils of the older collections from the Kialagvik formation have been referred by several paleontologists to different horizons in the Lower Jurassic (Lias) and Middle Jurassic (Inferior Oolite), but the more general opinion is that the fossils are Lias. These opinions have been cited in detail on pages 186–188. The later collections obtained by Capps and by Smith have been studied by Stanton, who believes that they are probably Middle Jurassic. In discussing the collections obtained by Capps, Stanton[78] made the following statements:

Lot No. 1–104 from Kialagvik [Wide] Bay contains the fauna, rich in ammonites, described by C. A. White many years ago from the same locality. Lots 1–107, 108, and 110 also have the same or a closely related fauna. The ammonites of this fauna are all different from those of the Tuxedni sandstone, which also has a varied ammonite fauna, but some of the other mollusks of the Kialagvik Bay fauna are identical with species found in the lower part of the Tuxedni sandstone. A faunal zone in No. 33 of the type section of the Tuxedni sandstone, 250 feet above the lowest bed of the formation there exposed, seems to be pretty definitely represented in lot 1–113, which I am assuming to be higher than 1–104. I judge therefore that lot 1–104 is not much older than the lowest fossiliferous bed of the Tuxedni Bay section and that its horizon may well be included in the Tuxedni formation. I would refer it to the lower part of the Middle Jurassic rather than to the Lias or Lower Jurassic.

The named species in this list were all originally described by White as found in a collection from Kialagvik Bay, probably from the same locality as the present lot. Pompeckj has referred the fauna to the upper Lias, and Hyatt said that the nearest relatives to the fauna are found in the "lowest parts of the Inferior Oolite, in formations placed by many German and French authors in the upper Lias." It is either basal Tuxedni or slightly lower.

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[77] Capps, S. R., op. cit., pp. 94–95.
[78] Stanton, T. W., cited by Capps, S. R., op. cit., pp. 96, 97.

This little collection permits pretty definite correlation with the lower part of the Tuxedni sandstone. The ammonite *Sonninia* and the *Inoceramus* are both identical with forms in No. 33 of Martin's Tuxedni Bay section (U. S. Geol. Survey Bull. 485, p. 61), which is 250 feet above the base.

Stanton also made the following statement[79] concerning lot 11358:

The fragment of a small ammonite (*Stephanoceras?*) in this lot is closely related to if not identical with a form in the Tuxedni sandstone and thus apparently gives another tie between the Tuxedni and the Kialagvik.

Fossils from Kialagvik formation[a]

	10804	10806	10807	10808	10809	11064	11065	11066	11349, 7570	11350	11351	11352	11353	11357	11358	11961
Cladophlebis?									b							
Rhynchonella									a							
Grammatodon	a		a													
Cucullaea increbescens White	a						a									
Cucullaea				a												
Pinna									a							
Gervillia											a					
Inoceramus lucifer Eichwald?		a			a				a			a	a	a	a	
Inoceramus (large, with coarse concentric ribs)														a		
Pteria			a													
Eumicrotis?				a												
Ostrea	a				a					a						
Trigonia (Costatae group)			a													
Trigonia (Glabrae group)			a							a	a					
Trigonia (Clavellatae group)			a													
Trigonia				a					a							
Pecten (smooth form)	a		a								a	a				
Pecten (ribbed form)	a	a														
Pecten (large, very coarse ribbed form)	a															
Pecten				a					a							
Lima cf. L. gigantea Sowerby	a											a				
Lima (small costate species)			a													
Anomia?	a															
Pleuromya dalli (White)	a		a			a	a			a	a					
Pleuromya					a											
Pleuromya?			a													
Thracia?	a															
Cypricardia?			a													
Tancredia?			a							a						
Protocardia	a			a						a						
Venerids?	a															
Turbo?	a															
Natica										a	a					
Cerithium			a													
Phylloceras	a															
Hammatoceras howelli (White)	a						a			a	a					
Hammatoceras cf. H. howelli (White)		a	a													
Hammatoceras cf. H. variabile (d'Orbigny)		a														
Hammatoceras? kialagvikense (White)	a			a		a				a						
Hammatoceras? cf. H. kialagvikense (White)			a													
Sonninia?					a											
Harpoceras whiteavesi (White)	a									a	a					
Dactylioceras?									a			a				
Stephanoceras?															a	
Belemnites	a				a		a	a	a				a			a

[a] a, Identified by T. W. Stanton; b, identified by Arthur Hollick.

10804 (1–104). Wide Bay, about 9 miles northeast of southwest end of bay and 1 mile southwest of mouth of Pass Creek. S. R. Capps, 1921.

10806 (1–107). Wide Bay, 3 miles from southwest end. S. R. Capps, 1921.

10807 (1–108). Same as 1–107, but 100 yards farther southwest along the shore. S. R. Capps, 1921.

10808 (1–110). Shore cliffs on point 2 miles from southwest end of Kialagvik Bay. S. R. Capps, 1921.

[79] Stanton, T. W., cited by Smith, W. R., and Baker, A. A., op. cit., p. 176.

10809 (1-113). On creek that enters Wide Bay from the northwest at southwest end of bay. Lowest collection from this creek. S. R. Capps, 1921.

11064 (E 1). Northwest shore of Wide Bay about 1¾ miles southwest of mouth of Desmoines Creek. Ernest Marquardt, 1921.

11065 (E 2). Northwest shore of Wide Bay, 1 mile southwest of mouth of Desmoines Creek. About the same horizon as 11064. Ernest Marquardt, 1921.

11066 (F 1). Northwest shore of Wide Bay near cabin at mouth of Desmoines Creek. Ernest Marquardt, 1921.

11349, 7570 (F 13). South shore at southwest end of Wide Bay. W. R. Smith, 1922.

11350 (F 14). West shore of Wide Bay south of Short Creek. Stratigraphically 150 feet above F 31. W. R. Smith, 1922.

11351 (F 31). Same locality as 104, Wide Bay. W. R. Smith, 1922.

11352 (F 15). Wide Bay, 1 mile up creek southwest of Short Creek. W. R. Smith, 1922.

11353 (F 16). Wide Bay, 1 mile up Short Creek. W. R. Smith, 1922.

11357 (F 30). 1 mile northwest of Lee's cabin at Wide Bay. W. R. Smith, 1922.

11358 (F 32). Float found by Ray Russell on point at Wide Bay. W. R. Smith, 1922.

11961. Near Lee's cabin, Wide Bay. Jack Lee, 1923.

TUXEDNI SANDSTONE (?)

The possible presence of the Tuxedni sandstone on the Alaska Peninsula has been suggested by Martin.[80] The reason for the suspicion that the Tuxedni sandstone may be represented in the Cold Bay district is the presence of fossils, identified by Stanton as *Eumicrotis?* cf. *E. curta* Hall, in two small collections obtained by James Casey and George Jamme, jr., from localities that were said to be on the "west shore of Dry Bay" and "near Becharof Lake." No other fossils that are indicative of the Tuxedni sandstone have been obtained near Dry Bay or Becharof Lake. It is possible, therefore, that these fossils actually came from some other region, or from another formation, or it may be that small areas of the Tuxedni sandstone have been overlooked in the reconnaissance surveys of this region. Fossils of this type have a great stratigraphic range in the Jurassic elsewhere.

It should be noted that the other fossils indicative of the horizon of the lower part of the Tuxedni sandstone were obtained by Capps (lot 10809, p. 190) in beds that he believed to be part of the Kialagvik formation and by Smith (lot 11358) in float material within the area of the Kialagvik formation. Neither of these collections contains any of the ammonites that are characteristic of the Kialagvik formation. The presence of *Inoceramus* cf. *I. eximius* Eichwald at locality 10802, on Wide Bay, within the supposed area of the Shelikof formation (p. 200), is also suggestive of the Tuxedni sandstone.

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[80] Martin, G. C., Preliminary report on petroleum in Alaska. U. S. Geol. Survey Bull. 719, pp. 59, 61, 1921.

UPPER JURASSIC

SHELIKOF FORMATION

Historical review.—The Shelikof formation was described by Capps[81] in 1922, to include all the Upper Jurassic rocks lying beneath the basal conglomerate of the Naknek formation at Cold Bay and neighboring localities on the northwest shore of Shelikof Strait. The Shelikof formation as defined by Capps includes an upper shale member, which has yielded only fossils that are not characteristic of any known horizon, and a lower member composed chiefly of sandstone with minor amounts of conglomerate and shale, which carries the fauna of the Chinitna shale. The lower member of the Shelikof formation and its fossils were described in several publications prior to that of Capps.

The Chinitna fauna of the Alaska Peninsula has been recognized in several old collections of fossils from localities the exact geographic position of some of which is more or less in doubt.

Some fossils collected by Ilia Wosnessenski from a locality "near Katmai" were referred by Grewingk[82] to the Jurassic and were described by him as including the following species:

Ammonites wosnessenskii, n. sp.
Ammonites biplex Sowerby.
Belemnites paxillosus?
Unio liassinus?

The two species of ammonites listed above were discussed briefly by Eichwald,[83] who regarded *Ammonites wosnessenskii* as very similar to *Ammonites dorochini* Eichwald, from the supposed Neocomian or Gault of Chisik Island, and *Ammonites biplex* as identical with a form referred by him to *Ammonites milletianus* D'Orbigny, and coming from the supposed Gault of an undescribed locality on the Alaska Peninsula.

Neumayr[84] stated that *Ammonites biplex* Grewingk is without doubt an Upper Jurassic *Perisphinctes* and that *Ammonites wosnessenskii* is an *Olcostephanus*.

These fossils were reexamined and described in detail by Pompeckj,[85] who has shown that three distinct horizons are represented,

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[81] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 90, 91, 92, 97–101, pl. 2, 1922.

[82] Grewingk, C., Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der Nord-West-Küste Amerikas mit den anliegenden Inseln: Russ.-k. min. Gesell. St. Petersburg Verh., 1848–49, pp. 121, 344–347, pl. 4.

[83] Eichwald, Eduard von, Geognostisch-palaeontologische Bemerkungen über die Halbinsel Mangischlak und die aleutischen Inseln, pp. 141–142, 145–146, St. Petersburg, 1871.

[84] Neumayr, M., Die geographische Verbreitung der Juraformation: K. Akad. Wiss. Wien Denkschr., 1885, p. 94.

[85] Pompeckj, J. F., Jura-Fossilien aus Alaska: K. russ. min. Gesell. St. Petersburg, 2d ser., Band 38, No. 1, pp. 239–282, 1900.

the ammonites being Callovian species of *Cadoceras*, the pelecypod (*Unio liassinus?*) being an Upper Jurassic *Aucella* (see p. 203), and the belemnite being an Upper Cretaceous *Belemnitella* (see p. 300).

The precise localities from which these fossils were obtained are doubtful. No rocks older than the Naknek formation crop out on the shores of Katmai Bay (pp. 208–209) or were recognized by Spurr or any subsequent observer along the trail between Katmai and Naknek Lake. The locality description "near Katmai" must therefore be regarded as probably only a very general designation that may include places as far distant as Cold Bay.

A large number of fossils collected by Peter Doroschin, a mining engineer who was in Alaska from 1847 to 1852, were described by Eichwald[86] in 1871 and referred to the Cretaceous (Neocomian or Gault). Most other writers have agreed that they are Jurassic, it having been shown by Neumayr[87] that they represent several different horizons and include especially Jurassic types of northern relationships, the faunas of the Callovian and Volga beds probably being represented. These fossils were obtained at several localities, mostly unspecified, on the Alaska Peninsula and Cook Inlet. A few of these localities were discussed[88] in Eichwald's general description of "the Miocene and Cretaceous formations of Aläska [=Alaska Peninsula] and the Aleutian Islands," but the statements there given as to the species occurring at these localities do not in all respects correspond with the localities given under the descriptions of the species. There are other contradictions—for example, a species is described as occurring in association with other named species which are in turn described as occurring only at other places. Most of the species were described as coming from "Aläska" or Alaska Peninsula ("Halbinsel Aläska"). These terms are probably synonymous, as the name "Aläska" was applied only to the Alaska Peninsula by the Russians. It is possible, however, that Eichwald was following the newer American usage rather than the older Russian usage and intended to use "Aläska" in a broader sense. It is certain that he included localities on Cook Inlet, such as Tuxedni Bay, in "Aläska,"[89] and it is consequently not certain that occurrences designated "Aläska" are on what we now regard as the Alaska Peninsula. The term "Insel Aläska," which he used in a few places, must also be regarded as indefinite.

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[86] Eichwald, Eduard von, op. cit., pp. 88–106, 138–200.
[87] Neumayr, M., op. cit., pp. 93–94.
[88] Eichwald, Eduard von, op. cit., pp. 90–91.
[89] Idem, pp. 192, 194, 199.

Jurassic fossils from Cook Inlet and Alaska Peninsula described by Eichwald

	Locality										Age according to Eichwald			
	Cook Inlet	Chisik ("Chasik") Island	Tuxedni ("Tukusitnu") Bay	"Island in Cook Inlet"	"North shore of Katchemak Bay"	"Aläska Peninsula"	"Aläska"	"Insel Aläska"	"North of Cape Unalischaglak"	Kodiak Island	Neocomian	Neocomian or Gault	Gault	"Black limestone of undetermined age"
Ammonites doroschini Eichwald		X										X		
Ammonites dutempleanus D'Orbigny aff	X											X		
Ammonites asterianus D'Orbigny aff		X	X										X	
Ammonites milletianus D'Orbigny aff						X							X	
Ammonites ishmae Keyserling	X					X			X		X		X	
Ammonites carteroni D'Orbigny aff				X										
Belemnites pistilliformis Blainville		X												
Belemnites inaequilateralis Eichwald		X											X	
Belemnites sicarius Eichwald						X						X		
Belemnites conformis Eichwald		X												
Trochus aleuticus Eichwald						X								
Trochus orientalis Eichwald							X				X			
Solarium conoideum Fitt										X	X			
Helcion striatum Eichwald							X				X			
Teredo socialis Eichwald aff								X						
Panopaea inflata Eichwald							X				X			
Panopaea aleutica Eichwald								X			X			
Panopaea dilatata Eichwald							X				X			
Panopaea protracta Eichwald							X				X			
Panopaea retracta Eichwald							X				X			
Panopaea alata Eichwald							X				X			
Panopaea aedilis Eichwald							X				X			
Panopaea rustica Eichwald							X				X			
Pholadomya scaphaeformis Eichwald							X				X			
Pholadomya panderi Eichwald							X				X			
Arcomya crassissima Eichwald							X				X			
Cucullaea insularis Eichwald						X					X			
Unio martini D'Orbigny aff							X				X			
Neaera gibba Eichwald							X				X			
Neaera striata Eichwald							X				X			
Neaera ? pumila Eichwald							X				X			
Arcopagia concentrica D'Orbigny							X				X			
Lyonsia alduini Fischer							X							
Venus ? abnormis Eichwald							X				X			
Cardium imbricatarium Leymerie D'Orbigny							X							
Cardium cooperi Gabb aff							X				X			
Cypricardia (Crassatella) trapezoidalis Romer aff						X					X			
Astarte germani Pictet and Campiche			X								X			
Astarte laevis Eichwald							X				X			
Crassatella exigua Eichwald							X				X			
Cardinia triangularis Eichwald							X				X			
Trigonia nana Eichwald			X								X			
Trigonia doroschini Eichwald			X								X			
Trigonia consobrina Eichwald							X				X			
Trigonia devexa Eichwald							X				X			
Pinna aleutica Eichwald							X				X			
Mytilus subrectus Eichwald							X				X			
Aucella mosquensis von Buch								X			X			
Aucella concentrica Fischer	X										X			
Avicula lineata Roemer							X							
Avicula rarocostata Eichwald						X					X			
Avicula volgensis D'Orbigny						X					X			
Inoceramus ambiguus Eichwald							X				X			
Inoceramus porrectus Eichwald			X				X				X			
Inoceramus eximius Eichwald			X								X			
Inoceramus lucifer Eichwald			X											
Inoceramus cuneiformis D'Orbigny						X								
Lima glabra Eichwald							X				X			
Lima punctum							X				X			
Janira foveolatum Eichwald						X								X
Pecten operculiformis Gabb					X									
Rhynchonella plicatilis Sowerby							X				X			

The only definite locality on the Alaska Peninsula cited by Eichwald as having yielded a species that is known to belong to the fauna of the Chinitna formation is noted as follows:[90]

A compact black limestone containing many ammonites and almost no other shells except a small specimen of *Cardium imbricatarium* and *Astarte germani*, is found on the eastern shore of the Alaska Peninsula north of the island [elsewhere Cape] Unalischachtak.

Cape Unalishagvak is the foreland between Portage Bay and Dry Bay, and the ammonites from this locality are described by Eichwald[91] as *Ammonites ishmae* Keyserling, which is stated to occur abundantly "at many places on the Alaska Peninsula and on the other islands." This ammonite is stated by Hyatt[92] to be the young of a species of *Cadoceras* that he recognized among Dall's fossils from Cold Bay. Hyatt stated furthermore that the Alaska ammonites described by Grewingk and Eichwald are, in his opinion, "all either Callovian or Inferior Oolite."

It was also pointed out by Pompeckj[93] that *Ammonites ishmae* Eichwald from "north of Cape Unalishaglak" and other Alaska localities is distinct from *Macrocephalites ishmae* Keyserling and is a Callovian species allied to *Cadoceras tchefkini* (D'Orbigny).

A large collection of Jurassic ammonites from Alaska was described by Pompeckj[94] in 1900. These fossils were described as coming from the "Sotkin'sches Ufer" of Kodiak Island, but no such locality is now known, nor have similar fossils been otherwise reported from Kodiak Island, so the position of the locality is more or less doubtful. The fossils were received by the museum of the Academy in St. Petersburg in 1859 and were collected by Dr. J. S. Petelin, junior surgeon of the Russian-American Co., while stationed on Kodiak Island. The labels indicate, according to a letter from T. Tolmachef, that Petelin's specimens may have come from several localities, some of them reading "Sookhom" or "Sookhom's shores." There is nothing on the labels that indicate that the locality is on Kodiak Island, the only connection with that island apparently being that the collector lived there. Copies of the labels, in Russian, were sent to Doctor Petelin's son, Rev. A. J. Petelin, of Afognak, who suggested that the specimens may have come "from the shores of the island of Sootkhom, originally named by Aleuts as

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90 Eichwald, Eduard von, op. cit., p. 91.

91 Idem, p. 147.

92 Hyatt, Alpheus, Report on the Mesozoic fossils: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, p. 908, 1896.

93 Pompeckj, J. F., The Jurassic fauna of Cape Flora, Franz Josef Land: The Norwegian north polar expedition, 1893–96 (scientific results edited by Fridtjof Nansen), vol. 1, No. 2, pp. 112, 138, 143, 1900.

94 Pompeckj, J. F., Jura-Fossilien aus Alaska: Verhandlungen der Kaiserlichen Russischen mineralogischen Gesellchaft zu St. Petersburg, Zweite Serie, Band 38, No. 1, 1900, pp. 239–282.

Sutwik, situated between Wrangell and Chignik," or "from Sootkhom Settlement, as at that time there was a village on the point of the mainland west of Sutwik Island which was known as Sootkhom."

The following species were described by Pompeckj as coming from this locality and were referred to the Middle Callovian:

Phylloceras subobtusiforme, n. sp.
Cadoceras wosnessenski Grewingk?
Cadoceras grewingki, n. sp.
Cadoceras schmidti, n. sp.
Cadoceras petelini, n. sp.
Cadoceras sp. indet.
Cadoceras steneloboide, n. sp.

Buckman[95] made the following statement concerning *Cadoceras grewingki* Pompeckj:

> This species is hardly a true *Cadoceras*, but it belongs to a series which in form and appearance is intermediate between *Cadoceras* and *Quenstedtoceras*. This species and its allies occur in the Kellaways Rock of Kellaways and havê been placed sometimes as *Ammonites mariae* D'Orbigny. The "Russian variety" which he figures by that name (Terr. jurassique: Céphalopodes, 1842–1849, pl. 179, figs. 7 and 8 only) belongs to the *grewingki* series, but the other examples are quite distinct. (See *Q. mariae*, p. 164.)

The first account of the rocks that are now included in the Shelikof formation was given by Dall,[96] who described very briefly the lithologic character of the fossiliferous beds which he observed at Cold Bay. The fossils collected by Dall were discussed by Hyatt,[97] who recognized a species of *Cadoceras* on the basis of which he concluded that the beds are of Callovian age. These rocks were described briefly by Martin[98] as the "Enochkin formation." They were also discussed briefly by Atwood,[99] whose account is based wholly upon the earlier descriptions.

In a later account of the oil fields of the Alaska Peninsula by Martin, the rocks of the Shelikof formation are described[1] as "sandstones, shales, and conglomerates carrying the fauna of the Chinitna shale" and are mapped[2] as "Middle Jurassic sandstone, shale, and conglomerate." This description was based on the investigations of Stanton and Martin in 1904 and includes stratigraphic sections, notes

[95] Buckman, S. S., The "Kelloway rock" of Scarborough: Geol. Soc. London Quart. Jour., vol. 69, p. 162, 1913.

[96] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Report, pt. 1, pp. 801, 870–871, 1896.

[97] Hyatt, Alpheus, Report on the Mesozoic fossils (appendix to Dall's Report on coal and lignite of Alaska): Idem, p. 908.

[98] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 52–53, 1905.

[99] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 32–33, 1911.

[1] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 59, 61–62, 1921.

[2] Idem, pl. 10.

on several exposures, and statements concerning the occurrence of fossils. Much of it had not been published previously.

The description of the Shelikof formation by Capps[3] was based on his own reconnaissance investigations of the area between Cold Bay and Wide Bay in 1921. It includes a brief general description of the lithologic character and sequence of the beds, accompanied by graphic columnar sections and by lists of the fossils collected by Capps and determined by Stanton.

The Shelikof formation was also described by Smith and Baker[4] on the basis of a geologic reconnaissance from Cold Bay to Chignik. Their description includes a general account of the character of the rocks with lists of fossils determined by Stanton.

A description of the Shelikof formation by Smith,[5] which was based on a geologic reconnaissance in 1923, includes a brief general account of the character of the rocks.

Stratigraphic description.—The Shelikof formation was described by Capps as including a lower member 1,500 feet thick, composed mostly of shale; a middle member 4,000 to 4,700 feet thick, composed of sandstone with minor amounts of conglomerate and sandy to calcareous shale that carry the Chinitna fauna; and an upper member 700 to 1,000 feet thick, composed of black shale with some limestone lenses in the upper part, carrying a fauna that is not characteristic of any known horizon.

The only localities where the base of the Shelikof formation was seen by Capps are at Cold Bay and on the creeks tributary to Wide Bay from the northwest. He described the lower member and the basal contact as follows:

> On Kialagvik [Wide] Bay the lower 1,500 feet of the formation is mostly shale, with some limy lenses and concretions. At Cold Bay the lower limit of the formation is placed at a conglomerate below which is 800 feet of shale that has been tentatively placed in the Lower Jurassic, though it may correspond to the basal shale of the Kialagvik Bay section and therefore properly belong in the Shelikof formation.

The part of the Shelikof formation lying between the basal and upper shales, according to Capps,

> comprises 4,000 to 4,700 feet of beds that consist dominantly of massive brown to gray sandstones, with minor amounts of shale and of conglomerate. In many places the sandstone is concretionary, the concretions ranging from small hard well-rounded spherical bodies a few inches to a foot or more in diameter to large irregular, poorly defined masses with indefinite boundaries.

[3] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 90, 91, 92, 97–101, pl. 2, 1922.

[4] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 169, 176–178, pl. 8, 1925.

[5] Smith, W. R., The Cold Bay-Katmai district: U. S. Geol. Survey Bull. 773, pp. 196–197, pl. 4, 1925.

The sandstone and included shale are locally calcareous and are in places so impure that they might well be called sandy shales.

The upper shale member was described by Capps as follows:

> Nearly every normal section shows that the uppermost member, lying immediately beneath the basal conglomerate of the Naknek formation, consists of a massive black shale from 700 to 1,000 feet thick which contains some limestone lenses and nodules. This shale is in places sandy and calcareous and is poorly fossiliferous.

The cliffs on the northeast shore of Cold Bay, according to the observations of the writer and his associates in 1904, contain a thick section of strata carrying the fauna of the Chinitna shale. These strata probably belong in the middle sandstone member of the Shelikof formation. Neither the bottom nor the top of these beds has been clearly recognized, for the contacts with the adjacent formations are probably faults. The contact of these beds with the underlying Lower Jurassic (?) shale and sandstone, which has been described on page 184, is about 1½ miles northwest of Cape Kekurnoi. Here the Lower Jurassic (?) rocks are either overlain by or faulted against soft brownish shale, several hundred feet thick, that is overlain by a heavy bed of coarse conglomerate. Above this conglomerate are sandstone and thinner interbedded strata of shale and conglomerate, which form the cliffs for about 2 miles and have an estimated thickness of probably 1,000 or 1,200 feet. The fossils contained in lot 3106 were obtained from a fine conglomerate near the top of these beds. The overlying rocks consist of massive sandstone, possibly 1,400 feet thick, overlain by 200 feet of dark shale. Near the top of the shale is a thin band with abundant fossils, as in lot 3105. Above the shale is coarse gray sandstone, apparently containing no fossils except *Belemnites*, probably 1,200 or 1,500 feet thick. These beds are separated by a fault from the rocks of the Naknek formation northwest of them.

The sandstone member of the Shelikof formation is also represented in the following section, which was measured by T. W. Stanton in the cliffs on the southwest shore of Cold Bay. The base of the section is at Cape Aklek and its top is at Lathrop's store. Neither the base nor the top of the formation is exposed.

Section of part of Shelikof formation on southwestern shore of Cold Bay.

	Feet
Shaly sandstone with some beds of shale and with *Belemnites*	800±
Coarse gray sandstone with thinner beds of more shaly sandstone and some bands of conglomerate. *Cadoceras*, *Phylloceras*, and *Belemnites* found sparingly from base to above the middle	1,000
Dark shaly sandstone, with some beds of shale and thinner bands and local lenses of conglomerate. *Belemnites* abundant in conglomerate about 100 feet above the base	400

The following section, which was measured by the writer about 10 miles southwest of Cold Bay, shows the character of the upper beds of this formation and the contact with the overlying rocks:

Section of part of Shelikof formation on hillside east of Rex Creek, 1 mile above head of Dry Bay

	Feet
Shale and sandstone (overlain by 600 feet of arkose, sandstone, and shale belonging to Naknek formation	500
Sandstone	90
Argillaceous shale	400
Sandstone, shale, and conglomerate	300

Age and correlation.—The fossils that have been obtained from the Shelikof formation are listed in the following table. The lower shale member of the formation is not known to have yielded any of these fossils, except possibly lot 10802, the stratigraphic position of which is uncertain. The next 32 lots in the tables are believed to have come from the middle sandstone member. The last 12 lots came from the upper shale member.

The fossils of lot 10802 include *Inoceramus* cf. *I. eximius* Eichwald. This fossil is suggestive of the Tuxedni sandstone.

The fauna of the middle sandstone member is characterized by several species of *Cadoceras*. The presence of *Cadoceras* indicates that the rocks are to be correlated with the Chinitna shale of Cook Inlet and that their horizon is at the base of the Upper Jurassic.

The fauna of the upper shale member, as now known, includes no fossils that are characteristic of special horizons. The position of this shale, immediately above the *Cadoceras*-bearing beds and under the conglomerate that forms the basal member of the Naknek formation, indicates that the shale belongs in the lower part of the Upper Jurassic. It is probably to be correlated either with the unfossiliferous shale in the upper part of the Chinitna shale (pp. 161, 163), or with the sparsely fossiliferous shale that has been assigned to the lower part of the Naknek formation of Cook Inlet (pp. 161, 172–173).

Fossils from Shelikof formation

	10802	3106	3105	10818	2944	3104	3104a	3103	10824	10826	3117	2945	10822	2943	3113	3112	(952)	3122	10787	10790	10788	11071	10800	10801	10803	10815	10805	10814	11072	10810	10811	10812	10813	3123	10819	3102	10791	10792	10793, 7516	11344	11323	11958	11346	11347	7571
Coniopteris burejensis (Zalessky) Seward																																							b						
Taeniopteris																																													c
Cidaris?																																											a		
Serpula																																							a						
Rhynchonella?			a																																										
Terebratula																a							a																						
Terebratula?																				a	a																a								
Solemya																																											a		
Nucula sp. a																																						a							
Nucula sp. b																																						a							
Nucula			a																			a																	a	a	a			a	
Leda			a																															a		a									
Grammatodon								a																							a		a					a	a	a		a	a		
Grammatodon?															a																														
Pinna																												a																	
Inoceramus cf. I. eximius Eichwald	a																																												
Inoceramus																					a						a	a																	
Avicula																																				a									
Avicula?			a																																										
Pteria										a																a		a	a				a		a			a	a	a	a		a	a	
Eumicrotis?																						a																							
Ostrea																																		a									a		
Pecten (smooth form)													a		a													a				a													
Pleuromya																				a								a				a			a										
Goniomya													a		a																														
Goniomya?																																												a	
Thracia																																a					a					a			
Thracia?																						a																a							
Astarte																												a				a		a		a				a					
Astarte?																																							a						
Corbis? (or Astarte)			a																																										
Cardium?																																									a				
Protocardia																																										a			
Venerid?																																										a			
Pelecypod																																		a								a			
Dentalium			a																																	a		a							
Turbo?									a																																		a		

Amberleya																											a				a							a							
Amberleya?															a																														
Rissoina?			a																																										
Tornatellaea?													a																																
Gastropod																																							a				a		
Burrow of a mollusk?																													a																
Phylloceras			a				a						a																		a					a									
Cadoceras catostoma Pompeckj									a																																				
Cadoceras doroschini (Eichwald)				a																																									
Cadoceras doroschini (Eichwald)?									a				a												a																				
Cadoceras grewingki Pompeckj?													a							a							a																		
Cadoceras schmidti Pompeckj														a																															
Cadoceras cf. C. schmidti Pompeckj																								a																					
Cadoceras stenoloboide Pompeckj																																	a												
Cadoceras wosnessenski Grewingk																																a													
Cadoceras		a	a			a	a	a			a				a		a	a	a							a			a		a														
Cadoceras? (with narrow umbilicus)																												a																	
Cadoceras?																							a							a															
Ammonite																															a														
Belemnites sp. a												a																																	
Belemnites sp. b												a																																	
Belemnites	a		a		a	a		a	a			a							a				a		a		a	a			a	a		a	a	a			a	a					

• a, Identified by T. W. Stanton; b, identified by F. H. Knowlton; c, identified by Arthur Hollick.

10802 (1–98). North shore of Wide Bay 1 mile south of mouth of Big Creek. S. R. Capps, 1921.

3106. Northeast shore of Cold Bay about 3 miles northwest of Cape Kekurnoi. Fine conglomerate. T. W. Stanton, 1904.

3105. Northeast shore of Cold Bay about 4 miles northwest of Cape Kekurnoi, or N. 16° W. of Lathrop's store. Thin fossiliferous bed at top of 200 feet of dark shale. T. W. Stanton, 1904.

10818 (1–126). North shore of Cold Bay 4 miles northwest of mouth of bay. S. R. Capps, 1921.

2944. Base of cliffs 2 miles southwest of Cape Yaklog. G. C. Martin, 1903.

3104. Southwest shore of Cold Bay near Cape Yaklog. Conglomerate 100 feet above base of bed 3 in section on p. 198. T. W. Stanton, 1904.

3104a. Southwest shore of Cold Bay near Cape Yaklog. From bed 2 of section on p. 198. T. W. Stanton, 1904.

3103. Southwest shore of Cold Bay 1 mile east of Lathrop's store or half a mile inside entrance to bay. Thin bed of conglomerate intercalated in sandstone and shale. T. W. Stanton, 1904.

10824 (C). Southwest shore of Cold Bay. S. R. Capps, 1921.

10826 (E). Creek that enters Cold Bay at store. S. R. Capps, 1921.

3117. Near head of small creek that enters Cold Bay at Lathrop's store. T. W. Stanton, 1904.

2945. Southwest shore of Cold Bay 1 mile above Lathrop's store. G. C. Martin, 1903.

10822 (3). Head of creek above store, Cold Bay. S. R. Capps, 1921.

2943. Near mouth of Oil Creek, Dry Bay. G. C. Martin, 1903.

3113. West side of Oil Creek, 500 feet above creek and half a mile above its mouth, or 4 miles west of Cold Bay. Calcareous nodules in sandy shale. T. W. Stanton, 1904.

3112. Oil Creek about 2 miles above its mouth, or 5 miles west of Cold Bay. Sandy shale. T. W. Stanton, 1904.

(952). Oil Creek about 250 yards below residue deposit. T. W. Stanton, 1904.

3122. Near head of Oil Creek. T. W. Stanton, 1904.

10787 (1). Dry Bay, three-fourths of a mile north of the mouth of Rex Creek, at an elevation of 1,150 feet. S. R. Capps, 1921.

10790 (1–57). About 3½ miles above mouth of Rex Creek. S. R. Capps, 1921.

10788 (2). East shore of Jute Bay half a mile south of head of bay. S. R. Capps, 1921.

11071 (L 10). East shore of Portage Bay. Ernest Marquardt, 1921.

10800 (1–95). About 1½ miles northeast of mouth of Big Creek, a tributary of Wide Bay at its northeast end. S. R. Capps, 1921.

10801 (1–96). Same as 1–95, but about 1,200 feet higher in section. S. R. Capps, 1921.

10803 (1–101). Wide Bay near barabara on point 1½ miles south of mouth of Big Creek. S. R. Capps, 1921.

10815 (1–119). Lee Creek, a tributary of Wide Bay; 3 miles above mouth of creek. S. R. Capps, 1921.

10805 (1–105). Wide Bay, stratigraphically 1,000 feet, more or less, above 1–104. S. R. Capps, 1921.

10814 (1–118). North shore of Wide Bay 4 miles from its southwest end. Loose boulder. S. R. Capps, 1921.

11072 (M 5). About 3 miles northwest of shore of Wide Bay, on creek that empties into bay 4 miles southeast of mouth of Lee Creek. Ernest Marquardt, 1921.

10810 (1-114). On creek that enters Wide Bay from the northwest at extreme southwest end of bay. Higher in the section than 1-113. S. R. Capps, 1921.

10811 (1-115). Same as 1-113 but higher in section. S. R. Capps, 1921.

10812 (1-116). Same as 1-115 but higher in section. S. R. Capps, 1921.

10813 (1-117). Same as 1-116 but higher in section. S. R. Capps, 1921.

3123. Southwest shore of Cold Bay near upper end, one-fourth mile north of the fault that cuts the conglomerate cliff. T. W. Stanton, 1904.

10819 (1-125). Head of Cold Bay, on west shore three-fourths mile southwest of mouth of lagoon. S. R. Capps, 1921.

3102. Southwest shore of Cold Bay, half a mile south of northwest end. Lower part of beds exposed in cliffs north of fault. T. W. Stanton, 1904.

10791 (1-60). About 300 feet below base of Naknek formation on Bear Creek-Porcupine Creek divide, 5 miles east-southeast of mouth of Bear Creek. S. R. Capps, 1921.

10792 (1-65). About 200 feet below base of Naknek formation on Bear Creek-Salmon Creek divide, 4¼ miles east-southeast of mouth of Salmon Creek. S. R. Capps, 1921.

10793 (1-79). About 300 feet below base of Naknek formation on shore of Portage Bay, half a mile southwest of Kanatak village. S. R. Capps, 1921.

7516 (1-79). Same locality as 10793. S. R. Capps, 1921.

11344 (F 1). Kanatak. Chinitna shale just beneath Naknek, 100 feet higher stratigraphically than 10793. W. R. Smith, 1922.

11323 (F 22 B 1). South side of Kanatak Creek valley. A. A. Baker, 1922.

11958 (1). Tributary of Kanatak Creek from the west about half a mile above wagon road and about 1½ miles north of Kanatak. Upper Jurassic (probably Chinitna shale). G. C. Martin, 1923.

11346 (F 8). West bank of head of north branch of Big Creek, Wide Bay. Shale just below Naknek formation. W. R. Smith, 1922.

11347 (F 11). Northwest end of Wide Bay. W. R. Smith, 1922.

7571 (P 9). Talus slope at head of Crooked Creek Pass. W. R. Smith, 1922.

NAKNEK FORMATION

Historical review.—Among the fossils collected by Wosnessenski near Katmai is a form identified by Grewingk[6] as *Unio liassinus?* and described by Pompeckj[7] as *Aucella* sp. indet. According to Pompeckj, this form is related to *Aucella bronni*. It was probably obtained from beds belonging to the Naknek formation.

Pavlow[8] believes that this specimen is referable to *Aucella lata* Trauschold and that it is Sequanian or Oxfordian. Pavlow believes also that some of the specimens of *Aucella* figured by Eichwald are Lower Portlandian[9], that possibly one of the specimens from

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[6] Grewingk, C., Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der nord-west-Küste Amerikas mit den anliegenden Inseln: Russ. k. min. Gesell. St. Petersburg Verh., 1848-49, pp. 121, 347.

[7] Pompeckj, J. F., Jura-fossilien aus Alaska: K. russ. min. Gesell. St. Petersburg Verh., 2d ser., Band 38, No. 1, pp. 270-271, 273-274, 282, pl. 7, fig. 5, 1900.

[8] Pavlow, A. P., Enchainment des aucelles et aucellines du crétacé russe: Soc. imp. naturalistes Moscou Nouv. mém., vol. 17(22), livr. 1, pp. 12, 81, 1907.

[9] Idem, pp. 22, 36, 38, 56, 81.

Port Moller figured by C. A. White may be Aquilonian or Upper Portlandian,[10] and that the specimens collected by Pinart and figured by Fischer are Lower or Middle Portlandian.[11] The specimens figured by Eichwald, White, and Fischer have been generally regarded as Lower Cretaceous. (See pp. 292–293.) If they are Upper Jurassic they probably came from the Naknek formation.

The Naknek formation was named and described by Spurr[12] as the Naknek "series." Spurr saw the rocks belonging to this formation only in the course of a rapid exploratory journey on which he crossed the Alaska Peninsula from Naknek Lake to Katmai, and his account of these rocks is consequently very general. This account includes descriptions of individual exposures, a general lithologic description of the series as a whole, a few short lists of fossils as determined by T. W. Stanton, and general discussions of age, correlation, and conditions of deposition.

Brief mention of the occurrence of the Naknek formation in the vicinity of Cold Bay was made by Martin,[13] but no detailed description was given.

The account of the Naknek formation by Stanton and Martin[14] contains no data relating to the Alaska Peninsula except statements regarding localities where it occurs, a general description quoted from Spurr, and descriptions of some of the exposures on Kamishak Bay.

The Naknek formation of the Herendeen Bay district was described very briefly by Paige[15] as the result of a hasty reconnaissance of the coal field. No formation name was used, and the rocks were described under the heading Upper Jurassic. This description includes merely a statement as to the presence of Upper Jurassic sandstone, with a list of fossils as determined by Stanton.

The account of the Naknek formation by Atwood[16] includes detailed descriptions of the Upper Jurassic rocks of the Chignik Bay and Herendeen Bay districts, with lists of fossils identified by T. W. Stanton, and a general description of the Upper Jurassic rocks of the eastern part of the Alaska Peninsula, based upon the earlier accounts of the investigations by Spurr, Stanton, and Martin.

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[10] Pavlow, A. P., op. cit., pp. 60, 81.

[11] Idem, pp. 22, 70, 81.

[12] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 145–147, 169–171, 179–180, 1900.

[13] Martin, G. C., The petroleum fields of the Pacific coast of Alaska: U. S. Geol. Survey Bull. 250, pp. 52–53, 1905.

[14] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 402–407, 1905.

[15] Paige, Sidney, The Herendeen Bay coal field: U. S. Geol. Survey Bull. 284, pp. 102, 104, 1906.

[16] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 25, 33–38, pls. 6–8, 1911.

The Naknek formation of the Cold Bay district was described by Martin[17] in an account of the oil fields of the Alaska Peninsula. This description was based in part on previous publications and in part on unpublished information obtained by Stanton and Martin in 1904. It includes a general discussion of the character and fauna of the Naknek formation of Alaska Peninsula and descriptions of some of the exposures near Cold Bay.

A description of the Naknek formation of the Cold Bay district by Capps,[18] based on a geologic reconnaissance in 1921, contains a detailed account of the character of the rocks, with columnar sections and lists of the fossils collected by Capps and identified by Stanton.

A geologic reconnaissance of the area between the headwaters of Becharof Lake and Chignik in 1922 was the basis of a further description of the Naknek formation by Smith and Baker.[19] This description includes a general discussion of the character of the formation, statements concerning the stratigraphy and structure at several localities, and lists of fossils collected by the authors and identified by Stanton.

Additional information concerning the Naknek formation of the area north of Cold Bay, including the type locality of the formation on Naknek Lake, is contained in a description by Smith,[20] based on a geologic reconnaissance in 1923. A general account of the formation is given, with local details and lists of fossils identified by Stanton from material collected by Smith.

A geologic reconnaissance along the axis of the Alaska Peninsula from Kamishak Bay to Naknek Lake in 1923 is the basis of a description of the Naknek formation by Mather,[21] which applies chiefly to the exposures on Kamishak Bay but in which brief statements are given concerning the exposures in the valleys draining into Naknek Lake.

A massive conglomerate that lies above the upper shale member of the Shelikof formation at Wide Bay and below the *Aucella*-bearing beds of the Naknek formation at several places in the Cold Bay district has been tentatively correlated with the Chisik conglomerate of Cook Inlet.

The conglomerate exposed at the base of the Naknek formation in the cliffs near the head of Cold Bay was mentioned briefly by

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[17] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, pp. 59, 62–63, pl. 10, 1921.

[18] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, pp. 90, 91, 101–105, pl. 2, 1922.

[19] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 169, 178–184, pls. 8, 9, 1925.

[20] Smith, W. R., The Cold Bay-Katmai district: U. S. Geol. Survey Bull. 773, pp. 198–201, 1925.

[21] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, pp. 169–171, pl. 3, 1925.

Martin.[22] The account of the Naknek formation by Capps[23] contains a detailed description of this conglomerate, which was described as the basal member of the Naknek formation, although a correlation with the Chisik conglomerate—at that time treated as a distinct formation—was suggested. This conglomerate was also described as part of the Naknek formation by Smith and Baker[24] and by Smith.[25] The occurrence of a conglomerate in the valley of Naknek Lake, which Mather compared with the Chisik conglomerate, has also been briefly described.[26]

Stratigraphic description.—The youngest Jurassic rocks known in the Alaska Peninsula have been grouped in the Naknek formation, which is composed of beds of arkose, conglomerate, sandstone, and shale aggregating several thousand feet in thickness and carrying a marine fauna characterized by species of *Aucella* related to *Aucella pallasi* and *Aucella bronni*, underlain by a series of conglomeratic beds ranging in thickness from 50 to 2,000 or 3,000 feet. The Naknek formation has been recognized at many places on the Alaska Peninsula from the shores of Cook Inlet to Herendeen Bay. It covers large areas, probably being the most extensive of the surface formations, and may be areally continuous throughout the greater part of the length of the peninsula. On the west coast of Cook Inlet the formation, as now defined by the Geological Survey, includes at the base the Chisik conglomerate member, 290 to 400 feet thick, and rests on the Chinitna shale. At other places on the peninsula it includes at the base a series of conglomeratic beds 2,000 to 3,000 feet thick and rests on the Shelikof formation. In previous reports the Chisik conglomerate has been treated as a distinct formation, but in view of its probable equivalence to some part of the much thicker conglomeratic series forming the lower part of the Naknek formation in other areas the Survey has recently decided to treat it as a local basal member of the Naknek.

This conglomerate in the Cold Bay district was described by Capps[27] as follows:

The basal member of the Naknek in this district is generally a coarse conglomerate that lies with structural conformity upon the top of the upper shale member of the Shelikof formation. The conglomerate shows great variations in thickness from place to place. At the head of Cold Bay there is a basal conglomerate 70 feet thick overlying the black-shale member of the Shelikof

[22] Martin, G. C., Preliminary report on petroleum in Alaska: U. S. Geol. Survey Bull. 719, p. 62, 1921.

[23] Capps, S. R., The Cold Bay District: U. S. Geol. Survey Bull. 739, pp. 90, 101–103, 115, 1922.

[24] Smith, W. R., and Baker, A. A., The Cold Bay-Chingnik district: U. S. Geol. Survey Bull. 773, p. 170, 1925.

[25] Smith, W. R., The Cold Bay-Katmai district: U. S. Geol. Survey Bull. 773, pp. 200–201, 1925.

[26] Mather, K. F., Mineral resources of the Kamishak Bay region: U. S. Geol. Survey Bull. 773, p. 170, 1925.

[27] Capps, S. R., op. cit., pp. 101–102.

formation and succeeded by gray arkosic sandstone containing scattered pebbles and some thin beds of fine conglomerate. At the head of Dry Creek the conglomerate has thickened to 200 feet, at Bear Creek to about 300 feet, at the head of Portage Bay to 500 or 600 feet, and at the head of Lee Creek to about 900 feet. In most places a massive coarse conglomerate lies directly upon the top of the Shelikof shale. Elsewhere coarse arkosic sandstone or alternating sandstone and thin conglomerate constitute the base of the formation, with the thick conglomerate higher in the section. At the head of Lee Creek a hastily studied section seems to show a lower conglomerate 900 feet thick overlain by about 1,200 feet of arkosic sandstone and conglomerate, which are in turn succeeded by a second conglomerate 800 feet or more in thickness. The Pearl Creek dome shows 1,500 feet of beds that include massive conglomerate, thin-bedded conglomerate, pebbly sandstone, and some shale, with the bottom of the formation not exposed.

The basal conglomerate of the Naknek consists of well-rounded pebbles and boulders of igneous rocks, the most conspicuous of which are gray granite and greenstone, in a matrix of coarse arkosic sand. In some places the boulders are of fairly uniform size. In others large and small boulders are mixed together. Granite boulders several feet in diameter are common, and well-rounded boulders 5, 6, and even 9 feet in diameter were seen.

The conglomerate described above has been generally regarded as the equivalent of the Chisik conglomerate of Chisik Island and Iniskin Bay, which is described on page 170. It certainly resembles and appears to correspond closely in position with the Chisik conglomerate, but its exact equivalence has not been shown beyond doubt. The upper shale member of the Shelikof formation, which underlies the conglomerate, may be the equivalent of the lower shaly beds of the Naknek formation of Cook Inlet, which they resemble in lithologic character and fauna at least as closely as they resemble the Chinitna shale. This conglomerate may therefore be the equivalent of some of the conglomeratic beds higher up in the Naknek formation of Cook Inlet.

The Naknek formation was first described as the Naknek "series" by Spurr.[28] The type occurrences are at the head of Naknek Lake and near Katmai. The original description is as follows:

About halfway from the mouth of Naknek Lake to the head of Savonoski there outcrops at the chief bend an ancient greenish volcanic rock, which is included under the general classification of the Naknek series. From this point to Savonoski the mountains on the south side of the lake are all of horizontal sedimentary rocks. From Savonoski nearly to the pass which separates the waters draining into Naknek Lake from those of the Katmai River the same sedimentary series occurs. At the pass the series is broken by a chain of volcanoes, but on the southeastern side it reappears and outcrops almost continuously as far as Katmai Point, which was the last place where it was observed. It will thus be seen that the rocks of the Naknek series, as here classified, occupy most of this section across the peninsula of Alaska.

As above noted, the westernmost rock of the Naknek series, as above understood, is an augite andesite which outcrops on Naknek Lake. It is

[28] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 145-147, 169-171, 179-180, 1900.

not absolutely certain that this rock represents a flow contemporaneous with the sedimentary rocks of the series, but in the absence of evidence this has been assumed, especially as the ancient and decomposed appearance of the rock suggests a different age from that of the later volcanic material, portions of which occupy the axis of the mountain range. The most of the rocks of the Naknek series, however, are arkoses, sometimes fine, sometimes coarse, and merging into conglomerates. These arkoses are either green, from the decomposition of ferruginous minerals and the production of chlorite, or light colored, from the predominance of feldspathic constituents. In nearly every case it is possible to tell under the microscope that the arkose has been derived from granite, and in some cases it is plain that the granite was a hornblende-biotite granite, all of the component minerals being found in very little altered and reassorted condition in the sedimentary rock. In the vicinity of Katmai and at Katmai Point the basal rock exposed just above tidewater is a hard, massive granitic arkose; above this comes a dense andesitic rock, which is perhaps a flow contemporaneous with the deposition of the sedimentary rocks; and higher up come arkoses, made up of very coarse granitic fragments, and coarse conglomerates, having pebbles of biotite granite.

At the coast in the vicinity of Katmai and for some miles inland are green arkoses, fine grained and granitic; there are also beds of conglomerate containing granite pebbles. The rocks in general are horizontal, although at the point which bounds Katmai Bay to the east they are uptilted on the sea side so as to dip very slightly to the northwest. There is also a system of nearly vertical fractures, and some slight faulting, but no folding. Along some of the seams are calcite veins. The rocks at this point are at the bottom hard and massive, dark-gray granitic arkose; above this comes massive andesite, probably a flow; while higher up are arkoses and conglomerates. About 200 feet above the base of the cliffs the arkose becomes nearly white and is found to be made up of coarse granitic fragments. Jurassic fossils are found in these rocks at various points, in gray compact limestone, which evidently comes from the upper part of the dark-gray grits that underlie the white arkoses, and also from the white arkose itself; indistinct plant remains are also frequent. The entire thickness of the horizontally stratified rocks exposed in the mountains near here is at least 1,500 feet. At Katmai Point a large dike of volcanic rock has burst through the grits.

The Naknek series consists of a great thickness of granitic arkose and of conglomerate, which generally contain pebbles of granite. All of these sedimentary rocks are evidently derived from the destruction of a land mass which consisted largely of hornblende-biotite granite. There are probably some volcanic flows interstratified with the arkose and conglomerates, although it is not absolutely proved that those examined may not be intrusive. The series is cut by andesite-basaltic (aleutitic) lava of later age, especially along the axis of the range, where the amount of volcanic rock is very great.

The rocks seen by Spurr include neither the base nor the top and possibly only a small part of the formation.

The exposures on the east shore of Katmai Bay described by Spurr were studied by Stanton and Martin in 1904 and were found to be composed of banded light and dark (mostly light) sandstone or arkose that has a striking resemblance to the banded sandstone overlying the *Cadoceras*-bearing beds in the Cook Inlet section.

(See p. 173.) The rocks on Katmai Bay were recognized as in general lithologically similar to and faunally identical with the Upper Jurassic beds of Cook Inlet and Cold Bay, which were accordingly referred [29] to the Naknek formation.

The exposures on the west shore of Katmai Bay are in low bluffs composed of dark-gray sandstone with thinner bands of lighter color and dark sandy shale; the beds become gradually less sandy toward the top and are in general fossiliferous throughout. The Naknek formation crops out almost continuously along the shore from Katmai River to Alinchak Bay and dips northward at low angles. This formation probably extends continuously through the hills from Katmai to the head of Cold Bay.

The rocks which Capps [30] referred to the Naknek formation were described by him as follows:

> Above the basal conglomeratic phase of the Naknek there is a variable thickness of light-gray to brownish-gray arkosic sandstone. Observed sections of this portion of the Naknek range in thickness from 500 or 600 feet to 1,600 feet, with an average of perhaps 800 feet. The sandstones generally contain pebbly beds and thin conglomerates, but very little shale. As described by Martin, the Naknek on the west shore of Cook Inlet contains arkosic sandstone, conglomerate, shale, and a considerable admixture of tuffs and andesite flows. In the Cold Bay district no igneous flows or tuffs were noted, and arkosic sandstone, derived from the disintegration of a granite mass, predominates in the part of the formation above the basal conglomeratic phase and below the upper sandy phase, described below. The arkosic sandstone is not generally very fossiliferous, but it has yielded enough collections to show that it should undoubtedly be included in the Naknek.
>
> The highest part of the Naknek formation that has been recognized in the Cold Bay district consists of a heavy series of sandy shales that lie above the arkosic sandstone. These shales are well developed between the extreme head of Becharof Lake and Mount Lee, where they have an estimated thickness of 1,200 feet, although their upper part has been removed by erosion. They are believed to have a wide development in the basin of upper Becharof Lake and to extend northeastward into the Kejulik (Garkulik) Valley, as well as in the basin of the Ugashik Lakes. The shales are locally fossiliferous and have yielded many forms of shells, the most common and most characteristic of which are several species of *Aucella*.

The Upper Jurassic rocks of the Chignik Bay district were referred by Atwood [31] to the Naknek formation and were described as consisting of sandstone, shale, and conglomerate, exposed in the main axis of the Aleutian Range. The base of the formation apparently does not crop out in this district, and the thickness of the exposed portion was not recorded. It is overlain unconformably (p. 297) by the Upper Cretaceous rocks of the Chignik formation.

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[29] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 402–407, 1905.

[30] Capps, S. R., The Cold Bay district: U. S. Geol. Survey Bull. 739, p. 103, 1922.

[31] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 34, 36–38, 1911.

The rocks exposed on the north shore of Ivanof Bay, according to the unpublished observations of the writer, consist of sedimentary beds, probably in part Upper Jurassic, that are separated by broad flats from the volcanic rocks that form the shores and islands farther down the bay. These sedimentary beds dip gently northward, so that the lowest beds, consisting of sandstone, are exposed at the west end of the cliffs. The sandstone is overlain by a massive conglomerate, above which is shale that forms the eastern half of the cliffs and appears to extend far up the mountain side. Concretions found among the boulders in one or two of the small gulches that head in this shale contain specimens (lot 7824) of *Aucella* related to *Aucella pallasi* Keyserling. As these gulches apparently contain no detritus other than that derived from the shale, this fossil indicates that the shale is Upper Jurassic and belongs in the Naknek formation. On the other hand, fossil leaves were found in sandstone beds that underlie and are intercalated in the massive conglomerate at the west end of the cliffs. These leaves are Upper Cretaceous or Tertiary. It is thus evident either that the *Aucella*-bearing concretions were not derived from the shale exposed in the cliffs or that the rocks exposed in the cliffs are not in their true sequence. The writer believes that the latter is the case and that there may be either an undetected fault between the shale and the apparently underlying conglomerate or an overturn of the entire section.

Upper Jurassic beds occur in several small areas at Herendeen Bay, where their presence was first noted by Paige.[32] They were subsequently described in greater detail as the Naknek formation by Atwood.[33] The following section, measured by Atwood, shows the character of the formation as exposed on Herendeen Bay:

Section of part of Naknek formation near the base of the east side of Pinnacle Mountain, near the head of Herendeen Bay

	Feet
1. Sandstone, coarse grained and fossiliferous (lot 5579)	600
2. Sandstone, medium grained (with a few fossils)	100
3. Sandstone, fine grained and fossiliferous (lot 5578)	50
4. Grit or coarse gritty sandstone	30
5. Sandstone, dark colored and very fine grained (lot 5573)	300

Conglomerate, which was not noted in this section, was observed at other localities. It probably belongs at a lower horizon than any of the beds represented in the section.

The base of the Naknek formation is apparently not exposed, and older rocks have not been found in this district. The Naknek formation is overlain at some places by the Lower Cretaceous beds of the Staniukovich shale, described on pages 291–292, and at other places

[32] Paige, Sidney, The Herendeen Bay coal field: U. S. Geol. Survey Bull. 284, pp. 102, 104, 1906.

[33] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 34–38, 1911.

by beds of unknown character described on page 299, that lie immediately beneath the Upper Cretaceous rocks of the Chignik formation and that may be either Upper or Lower Cretaceous. The contact with the Staniukovich shale is poorly exposed and may be either conformable or unconformable.

Age and correlation.—The Naknek formation carries abundant fossils, chiefly marine invertebrates, which are listed on pages 214–217. The apparent general absence of other than marine fossils is noteworthy, especially in view of the characteristic coarseness of the sediments. It was stated by Spurr[34] that plant remains are abundant throughout the formation, but apparently none were collected, and none were mentioned in his field notes. A few plants have been found, however, by later collectors. It should be noted that the fauna of the Naknek formation of most places on the Alaska Peninsula differs from that of the supposed equivalent beds on Cook Inlet in not containing *Cardioceras.* Specimens of this genus, which is characteristic of the lower (post-Chisik) beds that have been referred to the Naknek formation on Cook Inlet, have been found at only one locality on the Alaska Peninsula. The localities in the table are arranged approximately in geographic order.

(3) Upper end of Naknek Lake. Shingle of green sandstone or arkose on the beach near Savanoski. J. E. Spurr, 1898.

10249 (F). East arm of Naknek Lake, near Savanoski Camp. Sandstone in place and in loose slabs on lake shore. C. N. Fenner, 1919.

12081 (9). Float in tributary east of Savanoski River. W. R. Smith, 1923.

10246 (C). Cliffs of canyon a few miles east of Ukak Camp, Valley of Ten Thousand Smokes. C. N. Fenner, 1919.

10247 (D). Shaly strata at altitude of 2,500 to 2,900 feet, west spur of Buttress Mountain, Valley of Ten Thousand Smokes. C. N. Fenner, 1919.

10264 (H). Single specimen in sandstone in vicinity of Katmai Camp, south side of Mount Katmai. C. N. Fenner, 1919.

10265 (I). Shale with indistinct fossils from contact with one of the andesitic intrusions in vicinity of the "spire," north side of Valley of Ten Thousand Smokes. C. N. Fenner, 1919.

12080 (8). Baked Mountain, north side of Valley of Ten Thousand Smokes. W. R. Smith, 1923.

11960 (3) Near Valley of Ten Thousand Smokes. Jack Lee, 1923.

(4) Katmai Pass. J. E. Spurr, 1898.

(8) Five miles southeast of Katmai Pass. J. E. Spurr, 1898.

(2) Bluff above Katmai. J. E. Spurr, 1898.

(7) Bluff back of Katmai. J. E. Spurr, 1898.

(10) Katmai Point. J. E. Spurr, 1898.

3101. West side of Katmai Bay, 3 miles southeast of Katmai Village. Dark-gray sandstone with thinner bands of lighter color. T. W. Stanton, 1904.

3124. West side of Katmai Bay 2½ miles southwest of village, or half a mile south of lagoon. Talus of dark sandy shale that is somewhat higher than the beds that yielded lot 3101. Lawrence Martin, 1904.

3125. West side of Katmai Bay. Talus 200 feet north of 3124. Lawrence Martin, 1904.

[34] Spurr, J. E., op. cit., pp. 147, 170, 171.

3126. West side of Katmai Bay. Talus at same locality as 3125. Lawrence Martin, 1904.

3127. West side of Katmai Bay. Talus half a mile north of 3124 and at about the same horizon. Lawrence Martin, 1904.

3128. West side of Katmai Bay. Talus at same locality as 3127. Lawrence Martin, 1904.

10244 (A). Cliffs near beach camp, Katmai Bay. C. N. Fenner, 1919.

10248 (E). Highly fossiliferous stratum on Baer Mountain, near Lagoon Camp, Katmai Bay, north of camp and about 500 feet above sea level. C. N. Fenner, 1919.

12276 (3). Head of central and principal tributary of Bear Creek, flowing into north arm of Alinchak Bay, Alaska Peninsula. W. R. Smith, 1923.

10823 (B). Oilwell Creek, Cold Bay. S. R. Capps, 1921.

10825 (D). 5 miles northwest of head of Cold Bay. S. R. Capps, 1921.

11325 (22AB4). 3 miles up Teresa Creek from shore. A. A. Baker, 1922.

11332 (22AB5). 1 mile north of saddle at head of Teresa Creek. A. A. Baker, 1922.

3135. Creek entering marshes at head of Cold Bay, 1 mile from head and one-fourth mile up creek. Lawrence Martin, 1904.

3136. Creek entering marshes at head of Cold Bay, about 25 feet east of 3135. Lawrence Martin, 1904.

3131. Becharof Creek, half a mile above forks and 2½ miles east of Becharof Lake. Lawrence Martin, 1904.

3132. About 100 yards upstream from 3131, in somewhat lower beds. Lawrence Martin, 1904.

3133. About three-fourths mile above forks of Becharof Creek, in lower beds than 3132. Lawrence Martin, 1904.

3134. About 100 yards upstream from 3133. Lawrence Martin, 1904.

11333 (F 22 AB 6). West side of range across from Alinchak Bay. Basal Naknek. A. A. Baker, 1922.

11334 (F 22 AB 7). 1,600 feet southwest of junction of East Fork and Kejulik River. A. A. Baker, 1922.

11329 (F 22 AB 8). About 1 mile northwest of Kejulik River, about 2 miles southwest of point where two large tributaries come into river. A. A. Baker, 1922.

11330 (F 22 AB 9). 2 miles up from Kejulik River, along eastern tributary mentioned in 11329. A. A. Baker, 1922.

11331 (F 22 AB 10). In canyon near head of East Fork of Kejulik River. A. A. Baker, 1922.

11360 (F 34). Fossil Creek, north of Lake Becharof. Collected by Doctor Laymore for W. R. Smith, 1922.

11363 (F 37). Shale on bank of Kejulik River, northeast of Becharof Lake. W. R. Smith, 1922.

——— (F 38). Near mouth of Kejulik River. W. R. Smith, 1922.

12077 (4). East side of Kejulik Pass, below Gas Creek. W. R. Smith, 1923.

12078 (5). Upper part of Gas Creek, lowest exposed beds. W. R. Smith, 1923.

12079 (6). Mountain top east of Yori Pass. W. R. Smith, 1923.

10827 (1–130). 2 miles southeast of Bellim Bay, Becharof Lake. S. R. Capps, 1921.

10794 (1–80). Shore of creek between Lake Ruth and Becharof Lake at upper Indian village. S. R. Capps, 1921.

10817 (1-122). Southeast shore of Becharof Lake between extreme south end of lake and the fish village. S. R. Capps, 1921.

10795 (1-82). About 1,000 feet above base of Naknek shale, 3 miles southeast of Mount Lee and 1 mile west of shore of Becharof Lake. S. R. Capps, 1921.

10796 (1-83). About 1,000 feet above base of Naknek shale, three-fourths of a mile southeast of 1-82. S. R. Capps, 1921.

11324 (F 229 B 3). In gulch, 2,250 feet S. 60° E. from forks in Peulik Creek. A. A. Baker, 1922.

10797 (1-87). Basal conglomerate of Naknek formation. On Barabara or Little Ugashik Creek, about 1 mile below its head. Float boulder. S. R Capps, 1921.

7517 (1-88). Basal conglomerate of Naknek formation. Pearl Creek S. R. Capps, 1921.

7620. Top of bluff on south bank of Pearl Creek, N. 7° E. (magnetic) from Standard Oil derrick. G. C. Martin, 1923.

10798 (1-89). 5 miles southeast of Mount Peulik. S. R. Capps, 1921.

10799 (1-93). 5 miles south-southwest of Mount Lee. S. R. Capps, 1921.

10816 (1-121). Base of Naknek formation. Becharof-Crooked Creek divide. S. R. Capps, 1921.

11068 (G 3). Half a mile southwest of G 4. Ernest Marquardt, 1921.

11069 (G 4). On summit of Crooked Creek-Becharof Lake divide. Ernest Marquardt, 1921.

11070 (G 5). On ridge three-fourths of a mile north of G 4. Ernest Marquardt, 1921.

11345 (F 7). Across divide at head of Ugashik Creek. W. R. Smith, 1922.

3119. Kanata Bay, 12 miles southwest of Cold Bay. Received from Jack Lee, 1904.

11067 (F 7). Northeast fork of Big Creek, 2 miles above its mouth. Ernest Marquardt, 1921.

7572 (P. 10). East wall of canyon of Moore Creek, 3 miles from head. Thin-bedded sandstone in thick member of arkose in Naknek formation. W. R. Smith, 1922.

11073 (N 2). About 3 miles south-southwest of south end of Ugashik Lakes. Ernest Marquardt, 1921.

11354 (F 18). 8 miles southwest of Wide Bay. W. R. Smith, 1922.

11348 (12). Imuya Bay, south of Wide Bay. W. R. Smith, 1922.

11356 (F 26). East bank near head of Lava Creek. W. R. Smith, 1922.

11359 (F 33). Gates of crater at head of Aniakchak River. W. R. Smith, 1922.

3118. Hook Bay, on north shore of Chignik Bay. Received from C. J. Brun by T. W. Stanton, 1904.

5800. Hook Bay Creek near coal mine about 5 miles north of Hook Bay. W. W. Atwood, 1908.

5794. North side of Chignik Bay, on mountain top north of Bear Creek. W. W. Atwood, 1908.

5798. Chignik Lake. Fine-grained dark-colored sandstone exposed along the shore in the southwest arm of the lake. W. W. Atwood, 1908.

5799a. Chignik Lagoon, about opposite Alaska Packers' Association cannery. W. W. Atwood, 1908.

11959 (2). Hills between Chiaktuak Creek and Chignik Lake. Ernest Marquardt, 1923.

[For other localities see p. 218.]

Fossils from Naknek formation of Alaska Peninsula[a]

	(3)	10249	12081	10246	10247	10264	10265	12080	11960	(4)	(8)	(2)	(7)	(10)	3101	3124	3125	3126	3127	3128	10244	10248	12276	10823	10825	11325	11332	3135	3136	3131	3132	3133	3134	11333	11334	11329	11330	11331	11360	11363	(F 38)	12077
Cladophlebis cf. C. haiburnensis (Lindley and Hutton)																																										
Polypodium oregonense Fontaine																																										
Zamites megaphyllus (Philips) Seward																																										
Cidaris?																																										
Serpula															a																a											
Rhynchonella																	a																									a
Terebratula											a																															
Nucula																										a	a							a								
Leda?																																					a					
Grammatodon																																										
Arca																																										
Arca?																																										
Inoceramus																																										
Avicula											a						a											a			a	a										
Pteria																										a									a							
Eumicrotis			a																																							
Eumicrotis?																																										
Aucella cf. A. bronni Rouillier		a														a					a	a	a	a		a		a	a			a		a								
Aucella cf. A. erringtoni (Gabb)																																						a				
Aucella cf. A. pallasi Keyserling	a	a		a	a	a			a	a	a	a	a			a					a				a										a				a			
Aucella			a				a	a		a					a		a		a								a			a	a		a				a					
Ostrea																																										
Pecten sp. a																																										
Pecten sp. b																																										
Pecten (large, smooth form)																a			a			a																				
Pecten (smooth form)																					a																					
Pecten																										a		a								a	a					
Pecten? sp. c																																										
Lima								a														a	a												a	a	a	a				
Lima?																																					a					
Anomia?																																						a				
Pleuromya																						a	a			a								a				a				a
Pleuromya?																a			a										a			a										
Pholadomya																																										
Cypricardia?																															a	a										
Artica																							a																			
Cyprina																																										
Cyprina?																																										
Astarte			a												a		a																			a	a					
Astarte (same as in 10796)																																										

Astarte?														a													a															
Tancredia			a																		a																					
Tancredia?															a																											
Panopaea?															a																											
Dentalium																															a	a										
Patella																											a															
Turbo																						a																				
Turbo?								a																													a					a
Amberleya						a																																		a		
Natica										a																																
Rissoina??																																	a									
Gastropods (undetermined)															a						a						a															
Phylloceras		a														a			a			a																				a
Phylloceras? (coarse sculptured)																													a			a										
Phylloceras?																																										
Lytoceras																		a		a																						
Cardioceras cf. C. canadense Whiteaves																																										
Perisphinctes																																										
Ammonite																																										
Belemnites		a						a		a					a	a			a		a							a				a	a									a
Belemnites (slender form)																													a													
Belemnites (large phragmacone)																													a									a				
Crustacean																																										
Plesiosaur																																									c	
Bone fragment																																										a

[a] a, Identified by T. W. Stanton; b, identified by F. H. Knowlton; c, identified by J. W. Gidley; d, identified by Arthur Hollick.

Fossils from Naknek formation of Alaska Peninsula—Continued

	12078	12079	10827	10794	10817	10795	10796	11324	10797	7517	7620	10798	10799	10816	11068	11069	11070	11345	3119	11067	7572
Cladophlebis cf. C. haiburnensis (Lindley and Hutton)										b											
Polypodium oregonense Fontaine																					d
Zamites megaphyllus (Philips) Seward											b										
Cidaris?																		a			
Serpula																					
Rynchonella																					
Terebratula																					
Nucula																					
Leda?																					
Grammatodon																					
Arca																					
Arca?					a																
Inoceramus								a													
Avicula																					
Pteria					a								a								
Eumicrotis																					
Eumicrotis?	a		a																		
Aucella cf. A. bronni Rouillier				a			a					a	a			a	a				
Aucella cf. A. erringtoni (Gabb)					a	a		a				a									
Aucella cf. A. pallasi Keyserling			a																		
Aucella	a	a																	a		
Ostrea							a														
Pecten sp. a																					
Pecten sp. b																					
Pecten (large smooth form)																					
Pecten (smooth form)														a							
Pecten				a								a									
Pecten? sp. c																					
Lima																					
Lima?																					
Anomia?																					
Pleuromya		a	a										a				a		a	a	
Pleuromya?																					
Pholadomya																		a			
Cypricardia?																					
Arctica																					
Cyprina																					
Cyprina?																				a	
Astarte		a						a													
Astarte (same as in 10796)							a					a									

	11073	11354	11348	11356	11359	3118	5800	5794	5798	5799a	11959	7824	5574	5573	5578	5579	5581	5582	5583	5584	(Paige)
Cladophlebis cf. C. haiburnensis (Lindley and Hutton)																					
Polypodium oregonense Fontaine																					
Zamites megaphyllus (Philips) Seward																					
Cidaris?																					
Serpula																					
Rynchonella																					
Terebratula																a					
Nucula																					
Leda?																					
Grammatodon											a										
Arca														a							
Arca?																					
Inoceramus																					
Avicula																a					
Pteria																					
Eumicrotis													a	a		a					
Eumicrotis?																					
Aucella cf. A. bronni Rouillier	a			a				a		a			a	a	a						
Aucella cf. A. erringtoni (Gabb)		a																			
Aucella cf. A. pallasi Keyserling			a		a	a	a					a				a	a	a	a	a	a
Aucella																					
Ostrea																					
Pecten sp. a														a							
Pecten sp. b														a							
Pecten (large smooth form)																a			a	a	
Pecten (smooth form)																					
Pecten																					
Pecten? sp. c														a							
Lima			a					a		a											
Lima?																					
Anomia?																					
Pleuromya					a											a	a		a	a	a
Pleuromya?																					
Pholadomya																					
Cypricardia?																					
Arctica																					
Cyprina																a	a		a	a	
Cyprina?																					
Astarte																					
Astarte (same as in 10796)																					

Astarte?																																										
Tancredia			a																																						a	
Tancredia?									a																																	
Panopaea?																																										
Dentalium																																										
Patella																																										
Turbo																													a													
Turbo?												a																														
Amberleya							a																																			
Natica																																										
Rissoina??																																										
Gastropods (undetermined)																																										
Phylloceras				a	a	a	a	a				a						a	a																							
Phylloceras? (coarse sculptured)																																										
Phylloceras?															a											a					a											
Lytoceras																																										
Cardioceras cf. C. canadense Whiteaves												a																														
Perisphinctes							a																																			
Ammonite																							a																			
Belemnites				a				a					a						a				a						a									a			a	a
Belemnites (slender form)																																										
Belemnites (large phragmacone)																																										
Crustacean						a																																				
Plesiosaur																																										
Bone fragment																																										

[a] a, Identified by T. W. Stanton; b, identified by F. H. Knowlton; c, identified by J. W. Gidley; d, identified by Arthur Hollick.

7824. Float from north shore of Ivanof Bay and from creek 1 mile east of Perry. Probably derived from concretionary shale exposed in cliffs on north shore of the bay. G. C. Martin, 1912.

5574. Bold Bluff Point, Herendeen Bay. W. W. Atwood, 1908.

5573. East base of Pinnacle Mountain, Herendeen Bay. Bed 5 of section on p. 210. W. W. Atwood, 1908.

5578. Canyon on east face of Pinnacle Mountain, Herendeen Bay. Bed 3 in section on p. 210. W. W. Atwood, 1908.

5579. Canyon on east face of Pinnacle Mountain. Bed 1 of section on p. 210. W. W. Atwood, 1908.

5581–5584. Crow Point, Herendeen Bay. W. W. Atwood, 1908.

(Paige). Bluff south of Moss Valley, Herendeen Bay. Sidney Paige, 1905.

MATANUSKA VALLEY AND TALKEETNA MOUNTAINS

GENERAL FEATURES

The Matanuska Valley contains a thick and fairly complete section of Jurassic rocks, as follows:

General section of Jurassic rocks in the Matanuska Valley

	Feet
Upper Jurassic (overlain, conformably (?), by Lower Cretaceous beds):	
Naknek formation:	
Shale, sandstone, tuff, arkose, and conglomerate, with the fauna of the Naknek formation	1,000+
Unconformity.	
Conglomerate (Chisik?).	
Chinitna formation: Shale, conglomerate, and sandstone, with the fauna of the Chinita shale	2,000±
Conformity.	
Middle Jurassic:	
Tuxedni sandstone: Sandstone and sandy shale, with the fauna of the Tuxedni sandstone	1,000±
Conformity (?).	
Lower Jurassic: Lava, agglomerate, breccia, and tuff, interbedded with lesser volumes of sandstone and shale and containing fossil plants and a marine invertebrate fauna	3,000±
Basal contact and underlying rocks not exposed.	

The Jurassic section exposed in the Matanuska Valley is unfortunately incomplete in two important features. Neither the base of the Lower Jurassic volcanic rocks nor any older formation is exposed in this district, and some of the Jurassic faunas of the Alaska Peninsula (see pp. 181–191) are apparently absent. Otherwise the section appears to contain representatives of all the marine Jurassic faunas known in Alaska. The section is in general very similar, both lithologically and faunally, to the Cook Inlet section, of which it may be regarded as the detached northeastern extension.

The Lower Jurassic volcanic rocks of the Matanuska Valley resemble the rocks of the same age at Seldovia, on the east coast of

Cook Inlet, both lithologically and faunally, but differ from them by including plant beds. The Middle Jurassic beds of this district include beds which resemble, in a general way, the Middle Jurassic Tuxedni sandstone of the west coast of Cook Inlet and which contain a fauna that is practically identical with that of Cook Inlet. The Upper Jurassic rocks also are in general lithologically similar and closely related in faunas to the Chinitna shale and Naknek formation of the Alaska Peninsula and Cook Inlet. The Upper Jurassic rocks of this district are overlain conformably by Lower Cretaceous rocks. In this respect the section resembles that of the Alaska Peninsula and differs from that of Cook Inlet, where the Cretaceous is absent.

LOWER JURASSIC

TALKEETNA FORMATION

Historical review.—The Lower Jurassic rocks of the Matanuska Valley and adjacent areas have a wide geographic extent and constitute a very prominent stratigraphic and structural element in the geology of the eastern Talkeetna Mountains. For them the name Talkeetna formation is here proposed.

These rocks were first recognized by Paige and Knopf,[35] who described them as "greenstones and related pyroclastics" constituting the lowest member of the Middle Jurassic. Their account includes a brief statement concerning the petrographic character and stratigraphic relations of these rocks, together with a list of fossils and a statement of probable age contributed by T. W. Stanton, who referred the fauna tentatively to the Middle Jurassic.

The same authors redescribed these rocks in greater detail in a subsequent publication,[36] where they used the term "Lower Middle Jurassic rocks," including not only the volcanic members as described in the text but the whole of the "Middle Jurassic andesitic greenstones, etc.," as represented on the map. This account includes a more complete description of the petrographic character and stratigraphic relations than was given in the earlier account and includes also the list of fossils and discussion of age by Stanton, in which there is a suggestion of the subsequently confirmed correlation of these beds with the Lower Jurassic tuff of Seldovia.

These rocks were tentatively correlated by Brooks[37] with the Skwentna group of the Alaska Range, which he classified as "Lower Middle Jurassic" on the basis of Paige and Knopf's assignment of

[35] Paige, Sidney, and Knopf, Adolph, Stratigraphic succession in the region northeast of Cook Inlet, Alaska: Geol. Soc. America Bull., vol. 18, pp. 327–328, 1907.

[36] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 16–19, pl. 2, 1907.

[37] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 85–87, 1911.

their Matanuska Valley rocks. This account of the Skwentna group includes a brief abstract of the above-mentioned description of the Lower Jurassic tuff of the Matanuska Valley, with the list and discussion of the fossils quoted in full.

These rocks were described by Martin and Katz as Lower Jurassic "volcanic breccias, agglomerates, and tuffs." Their account includes a general description [38] of the occurrence throughout the Matanuska Valley, consisting of a series of slightly modified quotations from Paige and Knopf, also a detailed description [39] of the occurrence in the lower part of the Matanuska Valley, which is entirely new. The detailed account comprises a description of the occurrence and petrographic character, lists of marine invertebrate fossils as determined by T. W. Stanton, and a discussion of the age and correlation in which there is a hitherto unpublished statement contributed by Stanton, who concludes that the fauna should probably be referred to the Lower Jurassic and be correlated with the supposed Lower Jurassic tuff at Seldovia.

Some Lower Jurassic plants from the Matanuska Valley, collected by Martin and his associates in 1913 were described in detail by Knowlton,[40] who included in his paper a brief account of the stratigraphic occurrence contributed by Martin.

The character and distribution of the Lower Jurassic rocks in the northeastern part of the Talkeetna Mountains were described by Chapin,[41] who discussed the distribution, character, structure, thickness, age, and correlation of the rocks and quoted lists of fossils from previous descriptions.

The probable extension of these rocks in the western part of the Talkeetna Mountains has been described by Capps [42] as "andesite greenstones."

Stratigraphic description.—The Talkeetna formation of the Matanuska Valley includes lava, agglomerate, breccia, and tuff, interbedded with lesser volumes of sandstone and shale. It is composed chiefly of water-laid volcanic detritus. Its thickness is probably several thousand feet but can not be accurately estimated on account of the complex structure and the lack of recognizable horizons. These beds were deposited largely if not wholly in marine waters, although the fossil plants are possibly indicative of temporary terrestrial conditions. Neither the basal contact of these beds nor the rocks that underlie them have been observed. They are overlain

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[38] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley: U. S. Geol. Survey Bull. 500, pp. 17–19, pl. 3, 1912.

[39] Idem, pp. 29–32, pl. 5.

[40] Knowlton, F. H., A Lower Jurassic flora from the upper Matanuska Valley, Alaska: U. S. Nat. Mus. Proc., vol. 51, No. 2158, pp. 451–460, pls. 79–82, 1916.

[41] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 21, 29–32, pl. 2, 1918.

[42] Capps, S. R., Mineral resources of the western Talkeetna Mountains: U. S. Geol. Survey Bull. 692, pp. 195–196, pl. 4, 1919.

by the marine Middle Jurassic beds of the Tuxedni sandstone described on pages 223–226.

Age and correlation.—The fossils of the Talkeetna formation of the Matanuska Valley include the plants and marine invertebrates listed in the accompanying table. It is impossible, from the data at hand, to determine the exact position of the fossiliferous beds within the formation. The fossils all came from one lithologic unit or complex, which has not thus far proved to be stratigraphically divisible. It is possible, however, that this formation may contain more than one stratigraphic unit and that the plants and the marine shells are not of the same age.

The following statement regarding the age of the fossil plants has been contributed by F. H. Knowlton:

> Practically the whole of this flora is new to North America, the *Dictyophyllum* particularly being of interest, as this is the first time, so far as I know, that even the genus has been obtained here. The forms representing the genus *Otozamites* are also noteworthy.
>
> This flora is almost all identical with that at Bornholm, near the coast of Sweden, in beds regarded as of Liassic age, and for this reason the Matanuska material is considered to be of the same age. This is the oldest Jurassic flora known to me in North America.

Knowlton[43] has also made the following statements concerning the age of these plants:

> The Matanuska material undoubtedly finds its closest affinity with the material described by Nathorst, Bartolin, Möller, and others from the island of Bornholm, off the southern coast of Sweden, since all but two of the forms (*Pterophyllum rajmahalense* and *Ctenophyllum angustifolium*) are common to the two places.
>
> In the works of Möller, Nathorst, and others the Bornholm locality is referred to as Rhaetic or Liassic, there apparently being the same difficulty there as in many other parts of Europe in drawing the line between the Triassic and Jurassic. Taking everything into account in the present connection, such as the Jurassic affinity of certain of the forms, the absence of known plant-bearing Triassic rocks in Alaska, the apparently Lower Jurassic indication of the associated invertebrates, etc., all give weight to the reference of these rocks to the higher of the two alternatives. The material under consideration from the Matanuska Valley is therefore regarded as of Lower Jurassic (Liassic) age. This is the oldest well-defined Jurassic flora known to the writer in North America.

The following statement was submitted by Stanton[44] concerning the marine invertebrates collected in the lower Matanuska Valley in 1910:

> The lots numbered 6693, 6697, 6706–6709 are referred to the Jurassic, and are probably Lower Jurassic, though the paleontologic evidence for the latter

[43] Knowlton, F. H., A Lower Jurassic flora from the upper Matanuska Valley, Alaska: U. S. Nat. Mus. Proc., vol. 51, No. 2158, pp. 453–454, 1916.

[44] Stanton, T. W., cited by Martin, G. C., and Katz. F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 31, 1912.

reference is not so full as is desirable. The fossils are almost certainly from the same beds from which Mr. Knopf collected his lot No. 201, on the head of Matanuska River, in 1906. Mr. Knopf's collection was at that time doubtfully referred to the "Enochkin formation," but I am now inclined to consider the beds from which he collected equivalent to the supposed Lower Jurassic near Seldovia and to regard them as Lower Jurassic. It is true that not more than two or three species have been found common to the different localities from which these fossils have been collected, but the general character of the fauna in each case is suggestive of Lower Jurassic, and it is probable that more systematic collecting would prove that the different lots really belong to a single fauna.

The Lower Jurassic volcanic rocks of the Matanuska Valley bear some resemblance, both lithologic and faunal, to the supposed Lower Jurassic tuff near Seldovia, on the east coast of Cook Inlet, which is described on pages 134–137, but the tuff near Seldovia is not known to contain plant beds. The available evidence, as suggested by Stanton, is strongly suggestive of this correlation, but it can not yet be regarded as definitely established.

Lower Jurassic fossils from Talkeetna formation of Matanuska Valley [a]

	6697	6706	6707	6708	6709	6693	8569	8570	6700	6698	6701	6699	8565	8561	6AK20	8589
Cladophlebis hirta? Möller									a							
Dictyophyllum nilssoni (Brongniart) Göppert									a							
Sagenopteris?									a							
Otozamites pterophylloides Brongniart											a	a				
Otozamites bornholmiensis? Möller									a							
Pterophyllum rajmahalense Morris										a						
Pterophyllum aequale (Brongniart) Nathorst										a						
Ctenophyllum angustifolium? Fontaine										a						
Nilssonia polymorpha Schenk									a							
Pagiophyllum falcatum Bartolin									a							
Rhynchonella	b		b			b	b								b	b
Nemodon?																b
Gervilla?							b									
Ostrea			b				b	b								
Gryphaea?			b				b									
Cardinia?	b				b											
Trigonia																b
Trigonia? (of glabrae type)							b									
Trigonia?	b												b			
Pecten sp. a (smooth form)	b					b	b								b	
Pecten sp. b (strongly ribbed Vola type)	b	b				b	b	b						b	b	
Pecten sp. c (large, flat, coarse ribbed)						b										
Pecten sp. d	b															
Pecten (fine-ribbed form)							b	b								
Pecten			b	b												b
Lima															b	
Modiola							b									
Pleuromya															b	
Thracia?							b									
Astarte?															b	
Protocardia															b	b
Undetermined pelecypods				b												
Undetermined gastropods																b
Aegoceras?	b															
Sonninia																b
Deroceras?	b	b														
Undetermined ammonites							b									

[a] a, Identified by F. H. Knowlton; b, identified by T. W. Stanton.

6697. Doone Creek, at mouth of gulch, 3,950-foot point on traverse of August 30. Float. G. C. Martin, 1910.

6706. Creek entering Chickaloon River from west 1 mile above Government Bridge, altitude 2,000 feet. G. C. Martin, 1910.

6707. Creek entering Chickaloon River from west 1 mile above Government Bridge. Float from base of falls. G. C. Martin, 1910.

6708. Creek entering Chickaloon River from west 1 mile above Government Bridge. Float above falls. G. C. Martin, 1910.

6709. Creek entering Chickaloon River from west 1 mile above Government Bridge. Talus at altitude 2,200 feet. G. C. Martin, 1910.

6693. Creek entering Chickaloon River from west 1 mile above Government Bridge, altitude 2,200 feet. G. C. Martin, 1910.

8569. West side of Chickaloon River at mouth of creek, 3 miles above Government Bridge. Black limestone float. G. C. Martin, 1913.

8570. Same as 8569. Breccia float. G. C. Martin, 1913.

6700. Crest of spur between first and second tributaries entering East Fork of Boulder Creek above its mouth, altitude 4,780 feet. Shaly and cherty beds interstratified with tuff. R. M. Overbeck, 1913.

6698. About three-fourths mile up the next to the lowest creek entering the East Fork of Boulder Creek from the south. Sandstone and shale interbedded with tuff. J. B. Mertie, 1913.

6701. Float from same locality as 6698. G. C. Martin, 1913.

6699. Talus from cliff about one-third mile upstream from 6698. J. B. Mertie, 1913.

8565. Same creek as 6698, about 1¼ miles above mouth. J. B. Mertie, 1913.

8561. Near head of Boulder Creek. Collected by a prospector.

6 AK201. Tributary to Squaw Creek heading under 6,375-foot peak at east end of Sheep Mountain. Fossiliferous tuff associated with lava and coarse pyroclastic rocks. Adolph Knopf, 1906.

8589. Sheep Mountain, altitude 3,400 feet, on creek flowing southeast from 6,375-foot peak. G. C. Martin, 1913.

MIDDLE JURASSIC

TUXEDNI SANDSTONE

Historical review.—Overlying the Lower Jurassic volcanic rocks just described as the Talkeetna formation is a thick series of sandstone and sandy shale that carry the fauna of the Tuxedni sandstone of Cook Inlet. These rocks were first recognized by Paige and Knopf[45] and were described very briefly as a "series of graywackes, sandstones, shales, and subordinate conglomerates," which constitute the second-mentioned member of the rocks referred to the Middle Jurassic. A list of marine invertebrate fossils, as determined by T. W. Stanton, was given.

In a later and more complete description of the geology of this region, by the same authors,[46] the rocks now referred to the Tuxedni sandstone constitute the "sandstones and shales" described under the heading "Lower Middle Jurassic rocks" and an undifferentiated part of the "Upper Jurassic and upper Middle Jurassic" rocks rep-

[45] Paige, Sidney, and Knopf, Adolph, Stratigraphic succession in the region northeast of Cook Inlet, Alaska: Geol. Soc. America Bull., vol. 18, p. 328, 1907.

[46] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 10, 16, 17–18, 19, 1907.

sented on the map.[47] This account includes a brief description of the lithologic character and stratigraphic relations of the rocks and lists of fossils, with a statement of their age as determined by T. W. Stanton.

These rocks were described by Brooks,[48] as the upper member of the rocks which he correlated with the Skwentna group of the Alaska Range. This account of the Matanuska extension of the Skwentna group consists of an abstract of the description by Paige and Knopf, but the accompanying lists of fossils were given in full. Brooks also represented these rocks on his geologic map[49] as part of the "Upper Jurassic and upper Middle Jurassic" rocks and not as the Skwentna group, thus following the mapping by Paige and Knopf.

Another general description of these rocks, which includes practically all of the account by Paige and Knopf, has been given by Martin and Katz.[50]

The exposures of Middle Jurassic rocks in the hills between Caribou Creek and Nelchina River were reexamined in 1914 by Chapin,[51] who described them as the Tuxedni sandstone. The description includes a brief statement concerning the distribution and character of the rocks and a discussion of their age and correlation, with a list of some fossils collected by Chapin and identified by Stanton.

Stratigraphic description.—The Tuxedni sandstone of the Matanuska Valley is composed of sandstone and sandy shale. The thickness has not been accurately determined but is known to be at least several hundred feet and may be a thousand feet or more. The formation contains abundant marine fossils and was probably deposited wholly in marine waters, although some of the sandstone beds contain abundant poorly preserved vegetable remains, mostly water worn sticks and stems. The Tuxedni sandstone rests upon the Lower Jurassic volcanic rocks, described above, but the scarcity of well-marked bedding planes in those rocks makes it difficult to determine whether the contact is conformable or unconformable. The Tuxedni is overlain by the Chinitna formation, described below, with apparent conformity.

Age and correlation.—The fossils of the Tuxedni sandstone of the Matanuska Valley, as now known and as listed in the table (p. 226), consist chiefly of marine invertebrates. Some beds contain numer-

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[47] Idem, pl. 2.

[48] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 86–87, 1911.

[49] Idem, pl. 9.

[50] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 15, 20, 1912.

[51] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 21, 32–33, pl. 2, 1918.

ous fossil sticks and stems of indeterminate character, but only one determinable leaf has been collected.

The Tuxedni sandstone of the Matanuska Valley corresponds very closely in lithologic and faunal character, as well as in its relations to the overlying and underlying rocks, to the Tuxedni sandstone of the type district, on the west shore of Cook Inlet.[52] It differs from the Tuxedni sandstone of Cook Inlet in being apparently somewhat thinner and in containing a larger proportion of shaly beds than is shown in the type section on Tuxedni Bay. Its fauna, especially as represented in the large collection of lot 8567, shows no essential difference from that of the Tuxedni sandstone of Cook Inlet.

The other Alaskan rocks which carry this fauna and with which these beds may be correlated include at least part of the Tordrillo formation of the Alaska Range,[53] possibly part of the Middle Jurassic rocks of the Alaska Peninsula, and the tuffaceous slate of the lower Chitina Valley.[54]

The relative position of the Tuxedni sandstone among the Jurassic rocks in other parts of the world has not yet been definitely established. The fossils have not yet been fully studied, but they appear to indicate that the Tuxedni sandstone corresponds approximately to part of the Middle Jurassic or Lower Oolite of the European classification, possibly being Inferior Oolite or Bajocian.

8567. Second creek entering Boulder Creek from the north above the canyon (creek north of extreme west end of Anthracite Ridge), 3⅕ miles up creek. G. C. Martin, 1913.

6AK42. North face of Anthracite Ridge near west end, altitude 3,900 feet. Adolph Knopf, 1906.

8564. Tributary entering Boulder Creek from the southeast next below East Fork. Float, possibly in part Lower Jurassic. G. C. Martin, 1913.

8571. Creek entering Boulder Creek from the north 3 miles above East Fork, G. C. Martin, 1913.

8572. Altitude 4,200 feet on ridge west of creek that enters Boulder Creek from the north 3 miles above East Fork. G. C. Martin, 1913.

6AK157. Nelchina River 12 miles N. 17° E. of mouth of Billy Creek, 1 mile above trail. Adolph Knopf, 1906.

6AK98. Canyon entering Billy Creek from the east 2 miles above its mouth. Adolph Knopf, 1906.

6AK88A. Tributary of Caribou Creek from the west one-fourth mile above Billy Creek, altitude 4,050 feet. Adolph Knopf, 1906.

6AK88B. Same as 6AK88A. Boulder in stream bed. Adolph Knopf, 1906.

8548. North bank of Caribou Creek half a mile below Billy Creek. G. C. Martin, 1913.

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[52] Martin, G. C., and Katz, F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 59–64, 1912.

[53] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 87–90, 1911.

[54] Moffit, F. H., Geology of the Hanagita-Brenner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 25–27, 1914.

8585. North bank of Caribou Creek three-fourths mile below Billy Creek. G. C. Martin, 1913.

6AK196. Alfred Creek 7 miles above its mouth. Adolph Knopf, 1906.

8951. Small gulch tributary to Crooked Creek just north of Albert Creek. Theodore Chapin, 1914.

8949. South end of knob northeast of east end of Sheep Mountain. Theodore Chapin, 1914.

8950. North end of knob northeast of east end of Sheep Mountain. Theodore Chapin, 1914.

8588. Sheep Mountain at altitude of 3,400 feet on creek flowing southeastward from 6,375-foot peak. G. C. Martin, 1913.

Fossils from Tuxedni sandstone of the Matanuska Valley [a]

	8567	6AK22	8564	8571	8572	6AK157	6AK98	6AK88A	6AK88B	8584	8585	6AK196	8951	8949	8950	8588
Sagenopteris göppertiana Zigno [b]	×															
Undetermined corals			×													
Rhynchonella	×		×													
Terebratula	×									×						
Trails or burrows															×	
Grammatodon													×	×		
Nemodon?	×															
Cucullaea	×															
Pinna	×															
Inoceramus ambiguus Eichwald	×									×						
Inoceramus cf. I. ambiguus (young specimen)							×									
Inoceramus cf. I. lucifer Eichwald		×						×								
Inoceramus									×				×			×
Avicula	×			×												
Eumicrotis?						×										
Trigonia cf. T. dawsoni Whiteaves	×												×			
Trigonia													×			
Pecten (small smooth species)						×										
Pecten	×			×										×		
Pecten sp. a													×			
Pecten sp. b													×			
Camptonectes?	×															
Lima cf. L. gigantea Sowerby	×															
Lima?												×				
Pleuromya carlottensis Whiteaves?	×															
Pleuromya	×							×								
Thracia cf. T. semiplanata Whiteaves	×															
Thracia?	×															
Cyprina?	×												×			
Astarte?						×										
Protocardia	×												×			
Isocardia	×															
Pleurotomaria	×							×								
Amberleya	×		×													
Natica									×							
Nerinea	×															
Nerinea?			×													
Phylloceras								×	×							
Phylloceras?	×															
Oppelia?								×								
Sonninia?									×							
Sonninia?									×							
Stephanoceras cf. S. humphriesianum (Sowerby)	×										×					
Stephanoceras					×			×	×							
Stephanoceras?	×									×			×			
Sphaeroceras cf. S. oblatum (Whiteaves)	×															
Sphaeroceras					×											
Belemnites									×							

[a] Identified by T. W. Stanton except the plant.
[b] Identified by F. H. Knowlton.

UPPER JURASSIC

CHINITNA FORMATION

Historical review.—A thick series of shale, accompanied by beds of sandstone and conglomerate, overlies the Tuxedni sandstone. This shale carries a characteristic fauna similar to that of the Chinitna shale of Cook Inlet.

The presence of this fauna was recognized by Paige and Knopf,[56] who described it as occurring in an undifferentiated lower member of "a continuous stratigraphic succession of younger Middle Jurassic and of Upper Jurassic rocks." The rocks containing this fauna were not specifically described, nor were the species belonging to this fauna listed separately from the Upper Jurassic fossils of the overlying beds.

A later and more detailed account of the same investigations[57] includes lists of fossils from these beds as identified by T. W. Stanton. These fossils were recognized as indicating a fauna of "late Middle Jurassic age" occurring in rocks that were briefly described in general terms under the heading "Upper Jurassic." The rocks carrying this fauna were not specifically described.

An abstract of the above-mentioned account, including a quotation in full of Stanton's report on the fossils, was given by Brooks[58] under the heading "Upper Jurassic and upper Middle Jurassic rocks of Matanuska basin."

The list of the fossils from these beds, collected by Paige and Knopf and identified by Stanton, was quoted by Martin and Katz,[59] but without any description of the strata.

The Chinitna formation of the Matanuska Valley was first described as a distinct formation by Chapin.[60] This account includes a brief description of the distribution, character, structure, age, and correlation of the strata.

Stratigraphic description.—The Chinitna formation as exposed on Boulder Creek consists of shale and shaly sandstone with lesser amounts of conglomerate and massive sandstone. Calcareous concretions are abundant in the shale. This formation apparently occurs in a synclinal area in which it overlies the Tuxedni sandstone with apparent conformity and is overlain unconformably by

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[56] Paige, Sidney, and Knopf, Adolph, Stratigraphic succession in the region northeast of Cook Inlet, Alaska: Geol. Soc. America Bull., vol. 18, p. 329, 1907.

[57] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, p. 22, 1907.

[58] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 91, 1911.

[59] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 22, 1912.

[60] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 21, 33–34, pl. 2, 1918.

the Upper Jurassic Naknek formation. The thickness has not been accurately measured but is probably several thousand feet.

The occurrence of the Chinitna formation on the headwaters of Nelchina River, in the eastern part of the Talkeetna Mountains, has not been studied in detail. The rocks at one locality in this area were described in Knopf's field notes as blue shale, striking N. 15° W., dipping 10° NE., and containing numerous limestone nodules. The nodules are similar in lithologic character to float found at the same place and containing the fossils of lot 156 (below). The rocks at another locality on Nelchina River were described by Knopf as fossiliferous sandstone with a gentle eastward dip. The fossils of lot 185 (below) were obtained at this place. The formation apparently overlies the Tuxedni sandstone and is overlain by the Naknek formation in this area, but there is no available information as to whether the contacts are conformable or unconformable or as to the thickness.

Age and correlation.—The Chinitna formation of the Matanuska Valley, although containing a fauna very similar to that of the Chinitna shale of Cook Inlet and resembling that formation in its stratigraphic relations to the underlying and overlying beds, differs somewhat from it in containing a larger proportion of sandstone and conglomerate. In this respect it bears a closer resemblance to the *Cadoceras*-bearing beds of the Shelikof formation of the Alaska Peninsula than it does to the *Cadoceras*-bearing beds of the Chinitna shale of Cook Inlet.

The occurrence of *Cadoceras* in these beds shows that they are to be correlated approximately with the Callovian of Europe.

Fossils from Chinitna formation of Matanuska Valley [a]

	8573	8571	8576	6AK156	6AK185
Rhynchonella			×		
Cucullaea	×				
Avicula			×		
Gryphaea	×				
Trigonia			×		
Pecten			×		
Pleuromya	×				×
Cyprina	×				
Astarte	×				
Isocardia			×		
Cadoceras doroschini (Eichwald)		×	×		
Cadoceras (young specimens)				×	
Cadoceras?	×				×
Belemnites			×	×	×

[a] Identified by T. W. Stanton.

8573. Altitude 3,400 feet on north side of knob 1 mile north of Boulder Creek and about 3 miles above mouth of East Fork. G. C. Martin, 1913.

8571. Float from tributary to Boulder Creek from north 3 miles above East Fork. G. C. Martin, 1913.

8576. Tributary to Boulder Creek from the north 5½ miles above East Fork, about 3,000 feet up creek, altitude 3,300 feet. R. M. Overbeck, 1913.

6AK156. Near headwaters of Nelchina River, about 10 miles N. 10° E. of mouth of Billy Creek, altitude 5,000 feet. Limestone nodules, not in place. Adolph Knopf, 1906.

6AK185. Nelchina River 1½ miles east of trail crossing, or about 13 miles N. 27° E. of mouth of Billy Creek. Sandstone. Adolph Knopf, 1906.

NAKNEK FORMATION

Historical review.—The Upper Jurassic rocks of the Matanuska Valley include shale, sandstone, and conglomerate that carry the fauna of the Naknek formation of the Alaska Peninsula.

The rocks here referred to the Naknek formation were observed in 1898 by Mendenhall,[61] who included them in the "Matanuska series." This "series," which was referred to the Lower Cretaceous, is now known to include a great variety and thickness of rocks ranging in age from Lower Jurassic to late Tertiary. The only Upper Jurassic rocks specifically mentioned in Mendenhall's description are the conglomeratic beds on Nelchina River ("Bubb Creek").

The occurrence of Upper Jurassic strata in the Talkeetna Mountains was indicated by Martin[62] on the basis of fossils of unknown derivation found in a sandstone boulder in the bed of Chickaloon River.

Upper Jurassic strata were first recognized in this district by Paige and Knopf,[63] who described very briefly the *Aucella*-bearing Upper Jurassic sandstone of the upper Matanuska and Nelchina valleys.

In a subsequent account of the same investigations,[64] Paige and Knopf described the Upper Jurassic strata in considerably greater detail. This account includes descriptions of the strata, a report by T. W. Stanton upon a collection of fossils, and a discussion of the stratigraphic relations. These authors did not attempt to separate on their map the Upper Jurassic *Aucella*-bearing beds from the Middle Jurassic formations and erroneously included in the Jurassic, both on the map and in the description,[65] an "andesite-quartz-monzonite conglomerate" that is apparently of late Tertiary age.[66] They also described as Upper Jurassic the conglomeratic tuff and arkose[67]

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[61] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 307–308, 1900.

[62] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: U. S. Geol. Survey Bull. 289, p. 11, 1906.

[63] Paige, Sidney, and Knopf, Adolph, Stratigraphic succession in the region northeast of Cook Inlet, Alaska: Geol. Soc. America Bull., vol. 18, p. 329, 1907.

[64] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 20–23, pl. 2, 1907.

[65] Idem, pp. 21, 23.

[66] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, p. 38, 1918.

[67] Paige, Sidney, and Knopf, Adolph, op. cit. (Bull. 327), p. 21.

of the Billy Creek-Nelchina divide, which is here referred (p. 310) to the Lower Cretaceous.

A description of these rocks, consisting of an abstract of the account by Paige and Knopf but including the statement regarding the fossils in full, was given by Brooks[68] under the heading "Upper Jurassic and upper Middle Jurassic rocks of the Matanuska basin."

The account by Paige and Knopf was also quoted, with little modification, by Martin and Katz.[69]

A later account of these rocks, based upon additional field work on their northeastern extension in the adjacent part of the Nelchina Valley, has been given by Chapin.[70] In this account the Naknek formation was differentiated from the underlying strata. The account contains a general description of the character and occurrence of the rocks, lists of fossils as identified by T. W. Stanton, and a discussion of age and correlation.

Some ammonites collected by Martin from the Naknek formation on Boulder Creek in 1913 have been described by Reeside.[71]

Stratigraphic description.—The Upper Jurassic rocks of the Naknek formation as exposed on Boulder Creek consist of green sandy shale, several hundred feet thick, which rests unconformably upon the shale and sandstone of the Chinitna formation and is overlain unconformably by Upper Cretaceous and Tertiary rocks. A large part of the original thickness of the Upper Jurassic strata was probably removed during the erosion interval represented by the upper unconformity.

The rocks of the Naknek formation on the headwaters of Nelchina River and Billy Creek lie nearly horizontal and cover a large area. As exposed in this area, they include beds of shale, sandstone, and conglomerate. No details concerning the stratigraphic sequence are at hand, but it is known that the conglomerates, although some of them may be several hundred feet thick, occur for the most part as thin local lenses. The thickness of the formation is certainly more than 1,000 feet and is probably several thousand feet. It rests upon the Chinitna formation without known unconformity and is overlain, probably conformably, by the Lower Cretaceous rocks described on pages 310–315.

It is possible but by no means certain that the Chisik conglomerate of Cook Inlet is represented by a thick massive conglomerate in the

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[68] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 91, 1911.

[69] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 20–22, 1912.

[70] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 21, 36–38, pl. 2, 1918.

[71] Reeside, J. B., jr., Some American Jurassic ammonites of the genera *Quenstedticeras, Cardioceras,* and *Amoeboceras,* family Cardioceratidae: U. S. Geol. Survey Prof. Paper 118, pp. 9, 27–28, pl. 9, 1919.

eastern part of the Talkeetna Mountains adjacent to the upper Matanuska Valley. An exposure of this conglomerate on Little Nelchina River ("Bubb Creek") was mentioned briefly by Mendenhall[72] in a description of the "Matanuska series." The conglomerate was also described by Paige and Knopf,[73] who suggested a correlation with the Chisik conglomerate in the statement that its position is "probably near the base of the Upper Jurassic, like its analogue on the west coast of Cook Inlet."

This conglomerate was described and mapped by Chapin[74] as a distinct unnamed formation which he regarded as the probable equivalent of the Chisik conglomerate. It was described by Chapin as occurring in two belts. In one belt it lies unconformably on Lower Jurassic volcanic rocks and is overlain conformably by sandstone and sandy shale of the Naknek formation. The conglomerate of this belt was believed by Chapin to be "with little doubt the Chisik conglomerate." The conglomerate of the other belt he discussed as follows:[75]

> The conglomerate on Little Nelchina River and Idaho Creek is with less confidence also regarded as Chisik. Its lower contact is concealed, but it is believed to lie next above the Chinitna formation, which is of Middle Jurassic age. It is known by its fossils to be Upper Jurassic. It is overlain with apparent conformity by Upper Jurassic shales and sandstone of the Naknek formation. This conglomerate may be a member of the Naknek formation and may thus occupy a higher position among the Upper Jurassic rocks than the Chisik conglomerate, but probably not, for to assume that it occupies such a position is to assume also that the beds were brought to their present position by faulting, no evidences of which were seen at this place. By reason of their similar stratigraphic relation to the known Naknek rocks, their lithologic similarity, and absence of proof to the contrary the conglomerate on Little Nelchina River and the Chisik conglomerate that extends from Tyone Creek to Little Oshetna River are believed to be the same.

Age and correlation.—The rocks here described are referred to the Upper Jurassic and are correlated with the Naknek formation of the Alaska Peninsula and of Cook Inlet on the basis of similarity of fauna, of lithologic character, and of stratigraphic sequence. The presence of the two species of *Aucella* related to *Aucella pallasi* Keyserling and *Aucella bronni* Rouillier and of *Cardioceras martini* Reeside is the paleontologic basis of this age assignment and correlation.

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[72] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 308, 1900.

[73] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 22, 23, 1907.

[74] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pp. 21, 35–36, pl. 2, 1918.

[75] Idem, p. 35.

Fossils from Naknek formation of the Matanuska Valley [a]

	8574	8575	8579	8583	8581	6AK136	8952	8953	8954	8955	3317
Serpula?								a			
Inoceramus										a	
Avicula		a									
Pseudomonotis (Eumicrotis)			a		a						
Aucella cf. A. pallasi Keyserling			a								a
Aucella cf. A. bronni Rouillier				a	a	a					
Aucella	a						a		a		
Pecten	a										
Astarte		a									
Tancredia			a								
Tancredia?										a	
Isocardia		a									
Turbo							a				
Phylloceras		a									
Cardioceras martini Reeside		b									
Belemnites	a	a									

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside, jr.

8574. Lowest outcrop on creek entering Boulder Creek from the northwest 5½ miles above East Fork. Green sandy shale. G. C. Martin, 1913.

8575. Concretions on talus across creek from 8574, probably from about the same beds. G. C. Martin, 1913.

8579. Limestone Gulch, tributary to Billy Creek from the east. 300 feet below base of Lower Cretaceous limestone. G. C. Martin, 1913.

8583. Limestone hills east of Billy Creek. About 200 or 300 feet below base of limestone. G. C. Martin, 1913.

8581. Near Limestone Gap, east of Billy Creek. About 100 or 200 feet below base of limestone. G. C. Martin, 1913.

6AK136. One-quarter mile up creek entering Billy Creek from the west, 8 miles above its mouth. Adolph Knopf, 1906.

8952. North bank of Nelchina River just above Idaho Creek. Sandstone embedded with conglomerate. Theodore Chapin, 1914.

8953. Idaho Creek 1½ miles above its mouth. Theodore Chapin, 1914.

8954. Ridge between Little Nelchina River and Little Tyone Creek, 2 miles north of Idaho Creek. Theodore Chapin, 1914.

8955. Yacko Creek on claim "No. 10 above." Near base of Upper Jurassic, overlying conglomerate. Theodore Chapin, 1914.

3317. Boulder in Chickaloon River. G. C. Martin, 1905.

ALASKA RANGE (YENTNA AND SKWENTNA VALLEYS)

GENERAL FEATURES

The rocks of the Alaska Range, as exposed on Skwentna and Kichatna Rivers in the Yentna basin, consist chiefly of Lower (?) and Middle Jurassic strata. The Middle Jurassic sediments and the intrusive rocks that cut them occur in the synclinal axis of the mountains; the Lower Jurassic (?) volcanic beds form the eastern foothills. The Middle Jurassic beds are underlain, along the western front of the range, by Silurian or Devonian argillite, chert, and graywacke. Slaty rocks that are somewhat similar to these Paleozoic beds probably underlie the Middle Jurassic and possibly underlie

the Lower Jurassic (?) beds in the eastern foothills of the range on Kichatna River.

The general sequence in this district is shown in the following table:

General section of rocks in the Alaska Range on Yentna and Skwentna Rivers

	Feet
Middle Jurassic: Tordrillo formation (grit, sandstone, and argillite, with some conglomerate and limestone)	2,000–3,000+
Lower Jurassic (?): Skwentna group (dacitic and basaltic lava and tuff, interbedded with arkose and some chert and limestone)	1,000–4,000+
Paleozoic (?): Slate and phyllite, with some graywacke and grit, exposed in the Yentna Valley	2,000–3,000

LOWER JURASSIC (?)

SKWENTNA GROUP

Historical review.—The Skwentna group, which is possibly of Lower Jurassic age, occurs in the eastern foothills of the Alaska Range on Skwentna and Yentna Rivers. These rocks were first described as the Skwentna "series" by Spurr,[76] who assigned them to the Jurassic on the basis of a correlation with the rocks of the Naknek "series" and their geographic position in the general trend of the belt of known Jurassic rocks of southwestern Alaska. They were described as the Skwentna group by Brooks,[77] who assigned them to the "lower Middle Jurassic" on the basis of their stratigraphic position beneath the Tordrillo formation, which is known to be of Middle Jurassic age (p. 235), and on the basis of a correlation with Mesozoic lava and tuff of the Matanuska Valley, which were formerly considered as belonging in the Middle Jurassic but are now regarded (p. 219) as Lower Jurassic and herein named Talkeetna formation.

Stratigraphic description.—These rocks were described by Spurr as "a series of ancient and somewhat altered volcanics interstratified with tuffs. Besides these volcanic rocks there is sometimes carbonaceous chert and beds of arkose whose minerals show an evident derivation from granite."

The Skwentna group, according to Brooks,

consists chiefly of a complex of igneous rocks which are largely volcanic. Dacites predominate among these volcanic rocks, which include both lavas and tuffs. Some basalts were, however, also noted. With the volcanic rocks

[76] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 149–152, 180, 1900.

[77] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 85–87, 1911.

are associated some arkoses, but these were not studied in detail in the field, for they were identified only after microscopic investigation. A few cherts and one small belt of black limestone were also found intermingled with the volcanic rocks. The whole series is cut by many intrusions.

The thickness of these rocks has not been measured, and there are but few data upon which to base an estimate. Brooks[78] believed it to be from 1,000 to 4,000 feet or more.

Age and correlation.—The Skwentna group has yielded no fossils; consequently the only available evidence on its age consists in its stratigraphic relation to the associated rocks and its lithologic resemblance to other rocks of known age. The basal contact of the Skwentna group has never been observed, but, according to Brooks,[79] "it seems likely that the Skwentna group rests unconformably on the Paleozoic rocks of the Kichatna Valley," which he regarded as possibly Silurian or Devonian. The Skwentna group is overlain by the Tordrillo formation (p. 235), which includes beds that carry a Middle Jurassic fauna. The information at hand indicates that this contact is probably unconformable.

It has been shown by Brooks that these rocks resemble the Lower Jurassic lava and tuff of the Matanuska Valley (Talkeetna formation of this report), with which he provisionally correlated them. There is a considerable degree of probability in this correlation, but it should be pointed out that the Talkeetna formation contains a considerable volume of marine deposits and some plant beds, neither of which have been recognized in the Skwentna group, and that there are notable differences in the lithologic character of the rocks. The rocks of the Skwentna group bear a much closer resemblance to the porphyry and tuff[80] of the west coast of Cook Inlet and of Iliamna and Clark lakes, which do not include any known marine deposits but which are probably of Lower Jurassic age. The presence of chert and limestone suggests that the Skwentna group may possibly include Upper Triassic beds like those at Port Graham. (See pp. 49–50.) Martin[81] has suggested a correlation of the Skwentna group with the Triassic or Carboniferous volcanic rocks that include the ellipsoidal lava beneath the known Triassic beds of Kenai Peninsula, the Nikolai greenstone of the Chitina Valley, and the volcanic rocks occurring in this same general position in other parts of Alaska.

[78] Brooks, A. H., op. cit., pp. 55, 86.

[79] Idem, p. 87.

[80] Martin, G. C., and Katz., F. J., A geologic reconnaissance of the Iliamna region, Alaska: U. S. Geol. Survey Bull. 485, pp. 50–59, 1912.

[81] Martin, G. C., General features of Kenai Peninsula: U. S. Geol. Survey Bull. 587, table opp. p. 32, 1915.

MIDDLE JURASSIC

TORDRILLO FORMATION

Historical review.—The Tordrillo formation occupies the heart of the Alaska Range along the valleys of Skwentna and Kichatna Rivers. It was described originally as the Tordrillo "series" by Spurr,[82] who referred it tentatively to the Cretaceous, and was subsequently reexamined and redescribed by Brooks,[83] who discovered the fossils that establish its age as Middle Jurassic.

Stratigraphic description.—The Tordrillo formation, according to Brooks, consists of a series of grit, sandstone, and fine conglomerate, together with argillite and a few layers of limestone. The thickness is between 2,000 and 3,000 feet.

The lower third of the formation includes massive grit and sandstone, with some conglomerate and argillite, the latter mostly in the form of slate but locally altered to phyllite. The conglomerate includes pebbles that are apparently derived from the underlying Paleozoic rocks. The upper two-thirds of the formation is made up chiefly of argillite with some sandstone and a few beds of limestone.

On the west side of the Alaska Range the Tordrillo formation rests unconformably on the argillite, chert, and graywacke of the Tonzona group, which is believed to be of Devonian or Silurian age. On the east side of the range, in the Kichatna Valley, it appears to overlie unconformably some slate and phyllite that are probably Paleozoic and are possibly the equivalent of the Tonzona group. In the Skwentna Valley, according to Spurr, it overlies the rocks of the Skwentna group.

Age and correlation.—The fossils represented in the following table show that the Tordrillo formation includes beds that are the equivalent of at least part of the Tuxedni sandstone.

Fossils from Tordrillo formation of Alaska Range [a]

	2	4	6	7
Echinoid spine		×		
Inoceramus eximius Eichwald		×	×	
Inoceramus eximius?				×
Inoceramus lucifer Eichwald?		×		
Inoceramus (fragment of large form)	×			

[a] Identified by T. W. Stanton.

2. Kichatna River, opposite camp of July 9. A. H. Brooks, 1902.
4. About 3 miles southeast of Simpson Pass, near camp of July 10. A. H. Brooks, 1902.
6, 7. Near Rainy Pass, camp of July 14. A. H. Brooks, 1902.

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[82] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 153–155, 183, 1900.

[83] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 87–90, 1911.

UPPER SUSITNA VALLEY

GENERAL FEATURES

In many parts of the upper Susitna Valley there are large areas of unfossiliferous, somewhat metamorphic rocks of undetermined age that comprise slate, graywacke, and conglomerate, some or all of which may possibly be Jurassic. These rocks include the "Sushitna slates" described by Eldridge,[84] the "slates and schists of the Susitna and Talkeetna Valleys"[85] and the "undifferentiated Paleozoic rock in the headwater region of the Susitna"[86] described by Brooks, the "Jurassic (?) rocks"[87] and the "undifferentiated Mesozoic (?) rocks"[88] of the Broad Pass region described by Moffit, and the "argillites, slates, and graywackes" of the Chulitna Valley described by Capps.[89]

Although some of these rocks have been tentatively assigned to the Mesozoic and even to the Jurassic, no conclusive evidence of their age has yet been obtained. In the writer's opinion, there is no special reason for assigning them to the Jurassic rather than to the Triassic or Cretaceous, and they may even be Paleozoic. Consequently no further reference will be made to them here, and they will be discussed in a later chapter with other Mesozoic or older rocks of undetermined age.

The Upper Jurassic (?) conglomerate near the Roosevelt Lakes bears a closer resemblance to some of the known Jurassic rocks of Alaska than any of the aforementioned slaty rocks and consequently will be described below.

UPPER JURASSIC (?)

CONGLOMERATE NEAR ROOSEVELT LAKES

Jurassic rocks are possibly represented by a massive conglomerate which crops out a short distance southeast of the Roosevelt Lakes, in the southern foothills of the Alaska Range, near the headwaters of Susitna River. This conglomerate was described by Moffit[90] under the heading "Triassic rocks" and was mapped as an undifferentiated member of the Upper Triassic "slates, tuffs,

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[84] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 15–16, 1900.

[85] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 65, 1911.

[86] Idem, pp. 68–69.

[87] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 32–38, 1915.

[88] Idem, pp. 39–40.

[89] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 217–218, 1919.

[90] Moffit, F. H., Headwater regions of Gulkana and Susitna Rivers, Alaska, including accounts of the Valdez Creek and Chistochina placer districts: U. S. Geol. Survey Bull. 498, pp. 31–32, pls. 2, 4A, 1912.

arkose, calcareous sandstones, and limestones," although the fact that he considered this reference to the Triassic as purely tentative is clearly shown by the statement that the conglomerate "suggests the presence of younger Mesozoic or possibly Tertiary sediments." Moffit's description follows:

The heterogeneous character of the rocks associated with the Triassic limestones and the rocks immediately north of the limestones and apparently overlying them, especially a massive conglomerate a mile or more southeast of the Roosevelt Lakes, suggests the presence of younger Mesozoic or possibly Tertiary sediments in this region, but no fossils were found to support this possibility. The best exposure of this conglomerate is in the mountain between the branch of the tributary of Clearwater Creek heading against Windy Creek and the branch heading toward Roosevelt Creek. The western face of this mountain is a massive conglomerate made up almost entirely of igneous rocks, chiefly dark basic volcanics but with a considerable amount of granitic rock in a groundmass of tuffaceous material. The pebbles and cobbles are well rounded, and many of them are a foot or more in diameter. This conglomerate, although it forms a large part of the mountain, is restricted to a small area, probably less than 2 square miles. No similar conglomerate was seen at any other locality during the summer.

This conglomerate is at least 400 or 500 feet thick and may be 1,000 feet or more. It appears to overlie the Upper Triassic strata, but the nature of the contact is not known, and there is no other evidence of its age.

Comparison of the conglomerate near the Roosevelt Lakes with the possible equivalents in other districts shows that it bears a strong resemblance to the Upper Jurassic Chisik conglomerate of Cook Inlet, described on pages 170–171, and to the similar and presumably equivalent conglomerate described on pages 218, 230–231 as occurring at the base of the Upper Jurassic rocks of the Matanuska Valley. It also resembles the Lower or Middle Jurassic tuffaceous conglomerate near Taral, in the Chitina Valley, described on page 238.

CHITINA VALLEY

GENERAL FEATURES

The rocks of undoubted Jurassic age in the Chitina Valley include Middle and possibly Lower Jurassic rocks on the south side of the river near its mouth. The Jurassic rocks of the Chitina Valley were formerly described as including the Kennicott formation and other supposed Upper Jurassic rocks that occur in discontinuous areas scattered throughout various parts of the valley. These rocks, which are believed by the writer to be chiefly if not wholly Cretaceous, are described on pages 330–349.

LOWER (?) JURASSIC

TUFFACEOUS CONGLOMERATE NEAR TARAL

A belt of massive conglomerate extends parallel to and from 100 to 300 feet above the east bank of Copper River from Chitina River nearly to Taral. This conglomerate has been described by Moffit[91] as the lower member of the "Middle Jurassic rocks" and mapped as "tuffaceous conglomerate."[92] The account by Moffit includes a brief general description of the occurrence, character, and relations of these rocks. According to this description, it is a "massive conglomerate containing well-rounded pebbles and cobbles of argillite, diorite, greenstone, and quartz in a tuffaceous matrix." The conglomerate apparently rests unconformably upon Paleozoic (Carboniferous?) schist, although some of the contacts seem to be faults. It is at least 500 or 600 feet thick. The overlying beds consist of the Middle Jurassic fossiliferous tuff described on pages 239–240.

There is no available evidence as to the age of this conglomerate, except that it is younger than the Paleozoic (Carboniferous?) schist, which lies unconformably beneath it, and older than the Middle Jurassic tuff, which lies conformably (?) above it. The tuff carries the fauna of the Tuxedni sandstone and consequently belongs in the lower part of the Middle Jurassic. Moffit has assumed, in the absence of evidence to the contrary, that the conglomerate, being closely associated with the Middle Jurassic tuff and being somewhat akin to it in lithologic character, should presumably be regarded as its basal member and assigned with it to the Middle Jurassic. This reasoning is valid, and this assignment, if the local evidence alone is considered, should undoubtedly be accepted. But comparison of the local rocks with the Jurassic sections in other parts of Alaska shows that this tuffaceous conglomerate is entirely unlike the Middle Jurassic rocks of most other Alaskan districts and that it bears a closer resemblance to some of the Lower Jurassic rocks of Cook Inlet and other districts. (See pp. 134, 220.) There is an important difference in that the Lower Jurassic beds of the Cook Inlet and Matanuska districts are composed mainly of volcanic detritus and contain only very subordinate amounts of conglomerate. Such a difference may, however, be merely the expression of purely local conditions. The fact of general significance is that volcanic conditions were dominant along the Alaskan coast in Lower Jurassic rather than in Middle Jurassic time. There is consequently a presumption in favor of assigning volcanic beds of probable early Jurassic age to the Lower rather than to the Middle Jurassic. The

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[91] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 576, pp. 17, 18, 25–27, 1914.
[92] Idem, pl. 2.

argument is weakened, however, in this particular case by the fact that the undoubted Middle Jurassic rocks that overlie the conglomerate (see below) are also composed largely of volcanic detritus; but it may possibly be assumed that the volcanic detritus in the overlying undoubted Middle Jurassic rocks is of secondary rather than primary origin and is derived from Lower Jurassic volcanic rocks.

The only conclusion that can be reached at present regarding the age of the tuffaceous conglomerate is that it is probably early Jurassic and may be either Middle Jurassic or Lower Jurassic.

MIDDLE JURASSIC

TUFFACEOUS SLATE NEAR THE MOUTH OF CHITINA RIVER

The fossiliferous tuffaceous beds described by Moffit[93] as occurring on the south bank of Chitina River near its mouth and on the mountain south of Taral Creek include the upper fossiliferous member of the "Middle Jurassic rocks" as described in the text and the "tuffaceous slate" as represented on the map. The account by Moffit includes a brief general description of the occurrence, character, and relations of these beds; lists and statements regarding the age of the fossils, contributed by T. W. Stanton; and a general discussion of the possible relations of these rocks to the Mesozoic rocks of other Alaskan localities. The description is quoted below:

> The fossiliferous tuffaceous beds here grouped with the conglomerate are exposed on the south side of Chitina River near its mouth and form prominent cliffs along the river. They lie immediately east of the conglomerate and are thought to overlie it. The beds are composed of a dark fine-grained sandstone-like rock, slightly calcareous and showing numerous small flakes of mica on the cleavage surface. The rock is much jointed, slightly altered, and breaks down readily under the influence of the weather, forming talus slopes of angular platy fragments. A considerable amount of this rock is exposed along Chitina River, but it was not recognized farther south along Copper River, although its presence there was expected. Several small areas of unaltered brownish-gray sandstone found east of Taral, however, may represent a phase of the tuffaceous beds, now largely removed by erosion. On the ridge south of Taral Creek this sandstone contains much quartz, numerous grains of clear unaltered feldspar, and flakes of biotite in a calcareous cement, and also some small black spots which are thought to be organic remains but which are too imperfect for identification.

These rocks rest with apparent conformity upon the tuffaceous conglomerate described above. (See pp. 238–239.) The thickness has not been measured but is probably at least several hundred feet. No overlying beds have been observed.

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[93] Moffit, F. H., Geology of the Hanagita-Bremner region, Alaska: U. S. Geol. Survey Bull. 567, pp. 17, 18, 25–27, pl. 2, 1914.

Several small collections of marine invertebrate fossils have been obtained from a locality of indeterminate stratigraphic position, but probably in the lower part of the formation. The fauna, though small, is characteristic and shows that the rocks are of Middle Jurassic age and are the general equivalent of the Tuxedni sandstone of Cook Inlet, described on pages 140–158.

Middle Jurassic fossils from Chitina Valley [a]

	7231	7232	7233
Leda?	×		
Inoceramus ambiguus Eichwald?		×	×
Inoceramus (shell fragments)	×		
Ostrea	×		
Stephanoceras?	×		×
Perisphinctes?	×		

[a] Identified by T. W. Stanton.

7231. South bank of Chitina River about 1½ miles above its mouth. Theodore Chapin, 1911.
7232, 7233. Same locality as 7231. F. H. Moffit, 1911.

NUTZOTIN MOUNTAINS

GENERAL FEATURES

The presence of Upper Jurassic rocks in the Nutzotin Mountains is indicated by the fossils, notably by the occurrence of a supposed Upper Jurassic species of *Aucella*. It is probable that a great thickness of Jurassic rocks exists in this district, but complex structure, metamorphism, and the lack of detailed stratigraphic studies make it impossible to determine just what part of the Jurassic is locally represented, or how much of the known section is of Jurassic age. The uncertain features include not only the position of the boundary between the Upper Jurassic *Aucella*-bearing beds and the lithologically similar Lower Cretaceous *Aucella*-bearing beds, but the differentiation of the Jurassic and Cretaceous *Aucella*-bearing beds from an apparently unfossiliferous metamorphic complex that possibly includes older rocks of similar lithologic character.

The general sequence of the Mesozoic and associated rocks west of Chisana River, in the Nutzotin Mountains and the valleys southwest of them, was represented by Moffit and Knopf [94] as follows:

Quaternary	Gravels, till, and other unconsolidated deposits.
Tertiary	Volcanic rocks. Lignite-bearing formation, including shales, sandstones, lignite beds, etc.

[94] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 16, 1910.

Jurassic	Shales of Jacksina Creek. Shales, slates, and graywackes of the Nutzotin Mountains.
Triassic	Thin-bedded limestone of Cooper Creek.
Carboniferous or later	Lavas and pyroclastic beds—tuffs, volcanic breccias, etc. Shales of Skolai Pass.
Carboniferous	Massive limestone. Shales with some tuffs and lava flows. Basic lavas and pyroclastic beds, with some shale and limestone beds.

The same authors indicated the correlation of these rocks with those of the Chitina Valley as in the following table:[95]

Correlation of the formations on the east and south sides of the Wrangell Mountains

Era	System	East side of Wrangell Mountains	South side of Wrangell Mountains
Cenozoic	Quaternary	Stream and glacial gravel, sand, etc.	Stream and glacial gravel, sand, etc.
	Tertiary (Eocene)	Volcanics, shales, sandstones, lignite. Unconformity.	Volcanics, lignite-bearing beds. Unconformity.
Mesozoic	Cretaceous (?)	Shales, etc., in Beaver Creek region.	
	Upper Jurassic	Slates, graywackes, and conglomerates of the Nutzotin Mountains.	Kennicott formation. Unconformity.
	Upper Triassic	Limestone of Cooper Pass	Limestone - shale formation. Chitistone limestone.
Paleozoic	Upper Carboniferous	Limestone, slates, and volcanics.	

The general sequence of the rocks in the Nutzotin Mountains between Chisana River and the international boundary was indicated by Capps[96] as below.

Quaternary:
- Glacial deposits, gravels, volcanic ash, peat, and other unconsolidated materials.
- Glacial morainal deposits, with associated lava flows.

Tertiary:
- Conglomerates and unconsolidated gravels.
- Sandstones, shales, conglomerates, and tuffs, locally containing lignite.

Cretaceous:
- Shales, slates, and graywackes.

Jurassic:
- Shales, slates, graywackes, and conglomerates.

Triassic:
- Thin-bedded limestone of Cooper Pass. Possibly includes also part of the slates and graywackes of the Nutzotin Mountains.

[95] Moffit, F. H., and Knopf, Adolph, op. cit., p. 31.

[96] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 29–30, 1916.

Carboniferous:
- Lava flows.
- Massive limestone.
- Lava flows and pyroclastic rocks.
- Massive limestones and shales.
- Basic lavas and pyroclastic beds, with minor amounts of sediments.

Devonian:
- Lavas and pyroclastic beds, with considerable black shale.

In the following description only the *Aucella*-bearing shale on the border of the Nutzotin Mountains will be considered. It is highly probable that a large part of the apparently unfossiliferous slate and graywacke that constitute the main mass of the Nutzotin Mountains is also Upper Jurassic. As these rocks probably include Lower Cretaceous strata, however, and may also include some Jurassic beds older than the Upper Jurassic, as well as rocks that are even pre-Jurassic, and as the Upper Jurassic members of this aggregate have not been differentiated, the doubtful rocks will be classed with similar rocks of more or less uncertain age described on pages 480–487.

UPPER JURASSIC

AUCELLA-BEARING BEDS OF NUTZOTIN MOUNTAINS

Historical review.—The Upper Jurassic *Aucella*-bearing beds of the Nutzotin Mountains were first described by Brooks[97] as a part of the "Nutzotin series." The "Nutzotin series" as described by Brooks was a large aggregate which included the Carboniferous limestone of the upper White River and other pre-Jurassic rocks. It was assigned to the Carboniferous and Devonian. The Jurassic part of the original "Nutzotin series" includes part of the slate, graywacke, and associated beds exposed on Nabesna River, which Brooks considered as representing some of the older members of the "series," although they are now known to include some of the younger members. These rocks were described only briefly and in general terms.

The next account of these rocks was given by Mendenhall and Schrader[98] and was based upon the observations of Schrader. In this account these Jurassic rocks were included in what was described very briefly as the "Mesozoic series," which comprised rocks supposed to range from Triassic to Lower Cretaceous. Although the presence of Jurassic fossils was recognized by Stanton in the collections, no lists or account of the occurrence of the fossils and no specific description of the Jurassic strata were given.

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[97] Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the upper White and Tanana Rivers: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 359–360, 369, pl. 47, 1900.

[98] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, pp. 36–37, 1903.

Further mention of these rocks was made by Brooks in his summary of the geology of Alaska,[99] where he pointed out that Schrader had shown that most of the rocks of the Nutzotin Mountains are of Mesozoic age and formally abandoned the name "Nutzotin series" as a stratigraphic term.

The Jurassic *Aucella*-bearing beds of this district constitute part of the aggregate described as "Mesozoic rocks" and mapped as "Mesozoic sediments" by Moffit and Knopf.[1] This account contains descriptions of the supposed Jurassic strata, lists of fossils as determined by T. W. Stanton, and a discussion of the correlation of these rocks with those of neighboring districts.

These beds have been described also by Capps,[2] who did not differentiate them from the closely associated Lower Cretaceous strata. The area described by Capps adjoins and is the southeastern extension of the area described by Mendenhall and Schrader and by Moffit and Knopf. The account by Capps, like the earlier descriptions, was based on reconnaissance investigations and consequently includes only a general description. It is accompanied, however, by lists of fossils as determined by T. W. Stanton.

Stratigraphic description.—The Upper Jurassic rocks of the Nutzotin Mountain district west of Chisana River were described by Moffit and Knopf[3] as follows:

> The Jurassic system is represented in the Nabesna-White district by banded shales or slates, graywacke, and conglomerate. With these are associated sandstone and limestone in minor amount. This group of rocks is not well delimited and, as will be seen later, probably includes some Triassic sediments and possibly some of Cretaceous age.
>
> Jurassic fossils were collected from thin-banded gray and black shales on the east side of Notch Creek opposite the mouth of Wilson Creek and from dark shales on the west side of Jacksina Creek 4 miles above its mouth. Schrader found a few imperfect Jurassic fossils on the east side of Nabesna River almost directly opposite the locality last named.

The Upper Jurassic rocks of the Nutzotin Mountains east of Chisana River have not been differentiated from the closely associated and somewhat similar Lower Cretaceous strata. The following descriptions, given by Capps,[4] consequently apply in general to both the Jurassic and the Cretaceous beds:

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[99] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 230, 231, 1906.

[1] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, pp. 16, 27–32, pl. 2, 1910.

[2] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 47–53, pl. 2, 1916.

[3] Moffit, F. H., and Knopf, Adolph, op. cit., p. 28.

[4] Capps, S. R., op. cit., pp. 31, 50, 51, 52.

Shales and graywackes of Jurassic age have been recognized on Bonanza Creek, but their upper and lower limits were not determined. The fossiliferous rocks of Jurassic age lie stratigraphically above the thick section of unfossiliferous sediments which forms the Nutzotin Mountains, and the lower beds may be either Triassic or Jurassic, or they may be in part Jurassic and in part older.

The rocks that have yielded Jurassic and Cretaceous fossils on upper Bonanza Creek are dominantly shales and argillites, with much less interbedded graywacke than is present in the sediments which form the main mountain mass. Some fine conglomerates are present, and a little impure limestone was seen, but the shales preponderate greatly. The proportion of graywacke is greatest in the lowest part of the section exposed and decreases upward.

So many uncertain factors enter into such estimates as can be made of the thickness of the Mesozoic beds that only round numbers can be used. Where they are most extensive, in the Nutzotin Mountains, the unfossiliferous argillite and graywacke beds are so intricately folded and faulted that the beds may be many times reduplicated in any section examined across the range. They are continuously exposed, however, for a distance of 13 miles along Chisana Canyon and form mountains on both sides of the river which reach heights of 5,000 to 7,500 feet above the stream. It seems certain that the beds must be many thousand feet thick to form this mountain range. The younger, fossiliferous slates of known Jurassic and Cretaceous age, as exposed on Bonanza and Chathenda creeks, are of less intricate structure, for they have rather uniform monoclinal dips to the southwest. They may also be reduplicated by faulting, but if the series is not reduplicated the beds have a minimum thickness of 3,000 feet and may exceed that figure.

Structurally above the typical slates and graywackes of the Nutzotin Mountains, in the vicinity of the Chisana placer mines, is a series of shales and graywackes, with some conglomerate, which has yielded fossils that are possibly of Upper Jurassic age. Its lower limit is not known, but its upper part merges, without any observed stratigraphic break, into rocks that are similar in lithology but bear Lower Cretaceous fossils.

Age and correlation.—The supposed Upper Jurassic *Aucella*-bearing beds of the Nutzotin Mountains have yielded the fossils listed in the following table. These fossils have been referred to the Upper Jurassic because they include a species of *Aucella* that is related to the supposed Upper Jurassic species *Aucella bronni* Rouillier. The other fossils listed in the table are not characteristic of any horizon more definite than Jurassic or Cretaceous. The presence of *Aucella* cf. *A. bronni* is suggestive of a correlation with the Naknek formation of the Alaska Peninsula.

Fossils from Upper Jurassic Aucella-bearing beds of Nutzotin Mountains [a]

	(1443)	(1449)	(1454)	(1456)	5722	5723	8809
Aucella cf. A. bronni Rouillier					×	×	
Aucella							×
Aucella?	×	×					
Astarte?			×				
Tancredia?				×			
Undetermined pelecypods				×			

[a] Identified by T. W. Stanton.

(1443). Head of Nabesna River, locality 26 O. State talus apparently derived from a series composed of limestone or massive slate. F. C. Schrader, 1902.

(1449). Nabesna River east of camp of August 1, vicinity of Knob Point. Dark slaty limestone. F. C. Schrader, 1902.

(1454). Nabesna River 27 E. "From the same locality as 1449 but at a little higher geologic horizon." F. C. Schrader, 1902.

(1456). Nabesna River, mountain east of camp of August 1. Dark impure slaty limestone, associated with graywacke, shale or slate, sandstone, and conglomerate "at a still higher horizon than 1454." F. C. Schrader, 1902.

5722. Trail of Notch Creek. F. H. Moffit, 1908.

5723. Bluff near mouth of Jacksina Creek. From hard shale, much crushed and slickensided. Adolph Knopf, 1908.

8809. Claim No. 14 on Bonanza Creek. Black shale. S. R. Capps, 1914.

The fossils represented by the following list[5] are possibly also Upper Jurassic. They are obtained, however, from shale that occurs in close association with supposed Paleozoic rocks and that has unknown relations to the other Mesozoic rocks of the district. The fossils themselves contain no intrinsic evidence of their age, other than that it is Mesozoic and post-Triassic.

9109. Bryan Creek. From sandy shales apparently interbedded with supposed Carboniferous lavas. S. R. Capps, 1914:

Terebratula sp.
Inoceramus sp.
Pecten sp.
Pecten? sp.
Alaria? sp.
Ammonite (fragmentary imprint of an undetermined genus).

This lot is certainly Mesozoic and not older than Jurassic. The collection is too small and fragmentary for closer determination.

SOUTHEASTERN ALASKA

GENERAL SEQUENCE

Although Jurassic rocks cover considerable areas in southeastern Alaska, the Jurassic sequence is by no means complete, several of the characteristic Jurassic formations and faunas that are so well developed elsewhere in the southern part of Alaska apparently being absent here. The next younger marine sedimentary beds above the Triassic are the supposed Upper Jurassic *Aucella*-bearing beds. The interval between the Upper Triassic and the Upper Jurassic probably includes some volcanic rocks that may be Lower or Middle Jurassic and may be represented by some of the unfossiliferous metamorphic rocks, chiefly slate, graywacke, and greenstone. The age and relations of these metamorphic rocks are in general highly problematic. Some of these rocks have been regarded as the metamorphic equivalent of the Lower Cretaceous *Aucella*-bearing beds,

[5] Stanton, T. W., cited by Capps, S. R., op. cit., p. 53.

and this interpretation undoubtedly is in part correct. (See pp. 375–383.) Others have been assigned to the Carboniferous, for which there apparently is strong evidence. See pp. 93–94.) Another part of these rocks contain Aucellas of the Jurassic type. Still others, which have been included in the "Berners formation," contain poorly preserved fossil plants which indicate a Jurassic or Lower Cretaceous age, the evidence, though by no means conclusive, favoring an assignment to the Jurassic. The evidence from these plants and from the supposed Jurassic Aucellas is the only paleontologic evidence that Jurassic rocks are present in southeastern Alaska.

In assigning the unfossiliferous or poorly fossiliferous rocks of southeastern Alaska to the Jurassic, to the Cretaceous, or to the pre-Jurassic the writer has used a combination of paleontologic and physical evidence. The Aucellas of the Jurassic type occur in or associated with beds that contain volcanic deposits and do not contain granitic boulders. The Aucellas of the Cretaceous type occur in beds that contain only reworked volcanic material and are interbedded with conglomerate containing granitic boulders. This occurrence is in harmony with the facts known in other parts of Alaska, where volcanic beds are not known in the Cretaceous rocks and where the larger masses of granitic rocks are believed to have been intruded in early Jurassic time. It has been assumed, therefore, that if the beds contain unreworked volcanic material they are probably pre-Cretaceous or post-Cretaceous; if they are intruded by granitic rocks they are probably early Jurassic or pre-Jurassic; and if they contain boulders of granitic rocks they are probably late Jurassic or, more likely, post-Jurassic. Additional evidence on the age of the rocks may be obtained from the apparent continuity or discontinuity of the succession. For example, it is believed that beds which directly overlie the known Triassic rocks, with no evidence or with slight evidence of unconformity, like some of the interbedded sedimentary and volcanic strata of Gravina Island and near Juneau, are probably Jurassic rather than Cretaceous, whereas beds which overlie the Triassic or older rocks with a more evident unconformity and without the intervention of rocks of transitional character, or beds which are separated from the Triassic rocks by a considerable thickness of intervening strata, are more likely to be Cretaceous than Jurassic. All these criteria ought to be used with caution, and little confidence can be placed in one kind of evidence alone; but when several kinds of evidence agree, the age assignments may be made with considerable confidence.

The supposed Lower or Middle (?) Jurassic rocks of southeastern Alaska include breccia, tuff, and lava on Gravina Island, the Thane volcanic group of the Juneau district, and possibly the melaphyre

breccia of the Wrangell district. The Jurassic rocks of Gravina Island and the Juneau district are included in the following sections:

Section of Mesozoic rocks on Gravina Island[6]

	Feet
Lower Cretaceous (?): Conglomerate, graywacke, and black slate with *Belemnites*	800±
Unconformity.	
Upper Jurassic: Slate and limestone interbedded with tuff and containing *Aucella*	1, 200±
Lower or Middle Jurassic (?): Breccia, tuff, and lava	
Unconformity (?).	
Upper Triassic: Limestone, slate, and conglomerate	1, 600±

Stratigraphic section near Juneau[7]

Upper Jurassic (?):
- Douglas Island volcanic group (melaphyre flows, tuff, and agglomerates).
- Treadwell slate (black clay slate, with some conglomerate and considerable graywacke).
- Concealed (Gastineau Channel).

Lower or Middle Jurassic (?):
- Thane volcanic group:
  - Melaphyre tuff.
  - Limestone.
  - Tuff and slate.

Upper Triassic:
- Gastineau volcanic group:
  - Slate.
  - Andesitic tuff.
  - Calcareous slate with Upper Triassic fossils.
  - Andesitic lava with local lenses of slate.

Triassic or older:
- Perseverance slate (clay slate).

Paleozoic, with perhaps some infolded Triassic:
- Clark Peak schist (schistose rocks derived from slate, sandstone, limestone, and conglomerate).

The breccia, tuff, and lava of Gravina Island overlie the Upper Triassic rocks unconformably (?) and grade upward into finer-grained tuff which is interbedded with slate and limestone containing fossils that are probably Upper Jurassic. The Thane volcanic group rests with apparent conformity on the andesitic tuff, lava, and interbedded fossiliferous Upper Triassic sediments that make up the Gastineau volcanic group. The melaphyre breccias of the Wrangell district are known only in contact with metamorphic rocks of undetermined age and with granitic intrusive rocks.

[6] Compiled by the writer from information given by Chapin (U. S. Geol. Survey Prof. Paper 120, pp. 83–100, 1918).

[7] After Eakin, H. M., and Spencer, A. C., Geology and ore deposits of Juneau, Alaska: U. S. Geol. Survey Bull. — (in preparation), with age assignments by the writer.

None of these supposed early Jurassic rocks have yielded any fossils. They are assigned to the Lower or Middle Jurassic because of their position relative to the Upper Triassic rocks of Gravina Island and near Juneau and relative to the Upper Jurassic rocks of Gravina Island and because of their general similarity to the Lower Jurassic volcanic rocks of Cook Inlet, the Matanuska Valley, and Graham Island, B. C., and to the Middle Jurassic volcanic rocks of Graham Island and the lower Chitina Valley.

The supposed Upper Jurassic rocks of southeastern Alaska include slate, limestone, and tuff on Gravina Island; some graywacke, slate, argillite, conglomerate, and greenstone on Chichagof and Baranof islands; the Treadwell slate and Douglas Island volcanic group of the Juneau district; a part of the "Berners formation" of Berners Bay; some sandstone and volcanic rocks at Windfall Harbor, on Admiralty Island; and perhaps some andesitic lava interstratified with tuff, conglomerate, and graywacke on Prince of Wales Island.

The slate, limestone, and tuff of Gravina Island (see section on page 247) rest unconformably (?) on the supposed Lower or Middle (?) Jurassic breccia, tuff, and lava; are overlain unconformably by supposed Lower Cretaceous conglomerate, slate, and graywacke; and contain *Aucella* of the Jurassic type. The graywacke, slate argillite, conglomerate, and greenstone of Chichagof and Baranof islands are underlain conformably (?) by undifferentiated metamorphic rocks, part of which may be Upper Triassic, and contain *Aucella* of the Jurassic type. The Treadwell slate and the overlying Douglas Island volcanic group have yielded no fossils and have been assigned tentatively to the Upper Jurassic, because, as is shown in the section on page 247, they appear to overlie the supposed Lower or Middle (?) Jurassic rocks composing the Thane volcanic group, because they lie in the southern extension of the supposed Upper Jurassic rocks included in the "Berners formation," and because they contain volcanic beds. The "Berners formation" consists of slate and graywacke, with some interbedded greenstone, and contains in its upper part fossil plants which Knowlton believes to be probably Upper Jurassic. It is now separated into several mapped units of different ages. The supposed Upper Jurassic rocks of Windfall Harbor consist of sandstone interstratified with volcanic sediments which occur in close but undetermined relations with Permian rocks and which have yielded a species of *Pecten* that is "probably Jurassic." The rocks of Prince of Wales Island that are possibly Upper Jurassic include lava, tuff, conglomerate, and graywacke which have yielded no fossils but which are assigned tentatively

to the Upper Jurassic because they contain volcanic members and rest unconformably on granite intrusive rocks.

LOWER OR MIDDLE (?) JURASSIC

BRECCIA, TUFF, AND LAVA OF GRAVINA ISLAND

Historical review.—The supposed early Jurassic volcanic rocks of Gravina Island were mapped by Brooks[8] as part of the Vallenar "series," which includes Devonian limestone, schist, and slate and associated greenstone. Brooks gave no specific description of the rocks that are now believed to be Jurassic. These rocks were also mapped by F. E. and C. W. Wright,[9] without specific description, as part of the "Upper Carboniferous greenstone lava flows interstratified with volcanic tuffs and black slate" and as part of the "undifferentiated Paleozoic rocks." They were described by Smith[10] as "andesitic effusive rocks" of supposed Jurassic or Cretaceous age. They are the "lower series of purely igneous material" in the "Upper Triassic or Jurassic rocks" described by Chapin,[11] whose description includes an account of the distribution, character, stratigraphic relations, structure, origin, age, and correlation of not only these supposed early Jurassic volcanic rocks but of the overlying beds, which are described on pages 252–254 as probably Upper Jurassic, and of the slate and schistose greenstone of Tongass Narrows, which the writer believes may be Paleozoic.

Stratigraphic description.—The supposed Lower or Middle Jurassic breccia, tuff, and lava of Gravina Island (see section on p. 247) are part of the rocks which Chapin mapped as "greenstone and slate" and which are made up of an interbedded series of altered tuff, flows, and black slate, with some intrusive rocks, occurring on Gravina and Revillagigedo islands. These rocks, according to Chapin, consist essentially of volcanic breccia and tuff with interbedded black slate and water-laid fine-grained tuffaceous sediments. The detailed sequence of the volcanic rocks of Gravina Island has not been worked out. In general they may be divided into two parts—a lower series of purely igneous material, mainly coarse pyroclastic rocks and breccia, which are here referred tentatively to the Lower or Middle Jurassic, and an upper series of mixed water-laid tuff, black slate, and limestone, with porphyritic basic rocks of similar composition, evidently partly intrusive and partly explosive, which are described

[8] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, pp. 42–43, pl. 2, 1902.

[9] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pls. 1, 2, 1908.

[10] Smith, P. S., Notes on the geology of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 95, pp. 104–105, fig. 35, 1915.

[11] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo Islands, Alaska: U. S. Geol. Survey Prof. Paper 120, pp. 95–97, fig. 11, 1918.

(pp. 252–254) as probably Upper Jurassic. No sharp line separates the two parts, which Chapin did not differentiate on his geologic map. The black slate passes into green fissile tuff and this into more massive varieties, so that as a rule a sharp line of contact can not be drawn between them. By more detailed work the lower purely volcanic material might be separated from the upper mixed sedimentary and igneous material. The limestone bodies are too small to be shown on a map.

The base of the volcanic rocks is evidently the coarse breccia that overlies the Upper Triassic sediments of the west coast of Gravina Island. This breccia occupies the southern part of Dall Ridge and portions of California Ridge. It is a fine-grained green rock with large angular fragments set in a dense matrix of the same composition. It overlies the Upper Triassic rocks with apparent conformity according to Chapin but with probable unconformity according to Smith.

The volcanic breccia at the base of the series is evidently the product of volcanic explosions. The stratification of much of this igneous material and the conformable intercalations of slate and limestone show that at least portions of it were deposited in water. The pillow-like structure of some of the flows that occur with the fragmental rocks indicates that they also were subaqueous.

Age and correlation.—No fossils have been found in the supposed Lower or Middle Jurassic breccia, tuff, and lava of Gravina Island. The only local evidence on their age is that they overlie Upper Triassic rocks, with apparent conformity, according to Chapin, but with probable unconformity, according to Smith, and grade upward into finer-grained tuff interbedded with slate and limestone containing probable Upper Jurassic fossils. The local evidence therefore indicates that these rocks are either Lower or Middle Jurassic.

On Graham Island, one of the Queen Charlotte group, according to MacKenzie,[12] are the Maude formation, which is Lower Jurassic, and the Yakoun formation, which is Middle Jurassic. The Maude formation is composed of a lower part, made up of banded slaty and flaggy argillite, in places carbonaceous, and an upper part, consisting of feldspathic sandstone. Partly crystalline bituminous massive limestone is provisionally classed with the Maude formation. Near the top of the formation, where it begins to grade into the overlying Yakoun formation, the sandstone contains igneous material. The Maude formation, according to Stanton,[13] contains characteristic Jurassic (probably Lower Jurassic) fossils. Some Upper

[12] MacKenzie, J. D., Geology of Graham Island, B. C.: Canada Geol. Survey Mem. 88, pp. 39–51, 1916.

[13] Idem, pp. 46–47.

Triassic fossils were found in detached areas of rocks which were questionably referred to the Maude formation but which are more than 50 miles from any rocks of undoubted Maude age. The conformably overlying Yakoun formation consists chiefly of andesitic and basaltic pyroclastic rocks including water-laid agglomerate and and tuff, conglomerate, and lava, with possibly some intrusive rocks. Fossils contained in the tuff and tuffaceous sandstone, according to Stanton,[14] indicate a Jurassic age, the ammonites in two lots suggesting a correlation with the Middle Jurassic Tuxedni sandstone of Cook Inlet.

The character and position of these rocks suggest a correlation also with the Lower Jurassic agglomerate and tuff of Seldovia and of the Matanuska Valley or with the Middle Jurassic tuffaceous slate of the lower Chitina Valley.

MELAPHYRE BRECCIA OF THE WRANGELL DISTRICT

The supposed Jurassic rocks of the Wrangell district consist of schistose melaphyre breccia (greenstone) with intercalated tuff and flows and beds of slate and graywacke. These rocks were described by Buddington[15] as follows:

> The rocks assigned tentatively to the Jurassic system consist predominantly of schistose and altered porphyritic basic volcanic breccias, with a minor amount of interbedded tuff, slate, and graywacke, and flows. The most conspicuous feature of the rocks consists of the abundant black hornblende crystals that occur as phenocrysts in the fragments of the breccias. In the more massive phases plagioclase feldspars, in all stages of alteration to epidote, chlorite, sericite, and other secondary products, form the groundmass. In the more altered phases actinolite is an abundant constituent and the feldspars may be entirely altered to secondary products. In other districts less altered phases of what is possibly the same formation have been determined as augite melaphyre and andesite porphyry. The rocks are similar to the greenstones of the Juneau gold belt and of Gravina Island, in the Ketchikan district. For those in the Gravina area a Jurassic age has been suggested by Chapin, and the greenstone or schistose melaphyre agglomerate of this district may be of similar age, though no fossils were found to corroborate this conjecture, and the structural evidence is indeterminate.

THANE VOLCANIC GROUP

Historical review.—The melaphyre tuff, limestone, and slate which constitute the Thane volcanic group of Eakin and Spencer[16] are part of the rocks that Spencer earlier described as the "slate-greenstone band"[17] and part of the rocks that he mapped as "greenstone

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[14] MacKenzie, J. D., op. cit., pp. 50–51.

[15] Buddington, A. F., Mineral deposits of the Wrangell district: U. S. Geol. Survey Bull. 739, 1922, pp. 53–54.

[16] Eakin, H. M., and Spencer, A. C., Geology and ore deposits of Juneau, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[17] Spencer, A. C., The Juneau gold belt, Alaska: U. S. Geol. Survey Bull. 287, pp. 16–18, 1906.

(volcanic)"[18] and as the "slate-greenstone band."[19] They are also an undifferentiated part of the rocks that Knopf[20] mapped, in an area that includes both the Juneau district and the adjacent region on the north, as "greenstone" and are presumably represented in some of the rocks in the neighboring Eagle River[21] and Berners Bay[22] districts which Knopf described as augite melaphyre.

Stratigraphic description.—The Thane volcanic group (see section on p. 247) consists of melaphyre tuff underlain by limestone, beneath which there are interbedded tuff and slate. The total thickness of the group is probably about 5,000 feet. These rocks are underlain with apparent conformity by the andesitic tuff, lava, and interbedded Upper Triassic sediments that make up the Gastineau volcanic group. (See pp. 92–95.) They are believed to be directly overlain, though the waters of Gastineau Channel intervene, by the supposed Upper Jurassic Treadwell slate, which is described on pages 255–256.

Age and correlation.—No fossils have been found in the Thane volcanic group. The only evidence on its age is its position, apparently conformably above the Upper Triassic rocks that form the Gastineau volcanic group. As it resembles in composition and seems to hold the position of some of the Lower or Middle Jurassic volcanic rocks of other regions it is referred tentatively to the Lower or Middle Jurassic.

UPPER JURASSIC (?) SLATE, LIMESTONE, AND TUFF OF GRAVINA ISLAND

Historical review.—The supposed Upper Jurassic rocks of Gravina Island were mapped by Brooks[23] as part of the Vallenar "series," but he gave no description of these Jurassic rocks, and the beds which he did describe are now known to be Devonian. The Wrights[24] mapped these Jurassic rocks in part as "Upper Carboniferous greenstone" and in part as "undifferentiated Paleozoic rocks," but gave no description of any of the rocks that are now believed to be Jurassic. These rocks are part of the "Jurassic or Cretaceous andesitic effusive rocks" described by Smith.[25] They are also part of the "Upper Triassic or Jurassic greenstones and slates" described

[18] Spencer, A. C., op. cit., pl. 4.
[19] Idem, pl. 37.
[20] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pl. 5, 1912.
[21] Idem, pp. 13–14, 18–20, pl. 2.
[22] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, p. 15, 1911.
[23] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, pl. 2, 1902.
[24] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pls. 1, 2, 1908.
[25] Smith, P. S., Notes on the geology of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 95, pp. 104–105, fig. 35, 1915.

by Chapin,[26] whose description includes a rather full account of the distribution, character, stratigraphic relations, structure, origin, age, and correlation not only of the rocks that are here referred to the Upper Jurassic but of the underlying coarse volcanic beds which have been described (pp. 249–251) as probably "Lower or Middle Jurassic (?)" and of slate and schistose greenstone on Tongass Narrows which the writer believes are Paleozoic or possibly Triassic.

Stratigraphic description.—The base of the greenstone and slate series of Gravina Island is evidently the coarse breccia found along the west coast, which has been described (pp. 249–251) as probably Lower or Middle Jurassic. The breccia was believed by Chapin to overlie the Upper Triassic sediments with apparent conformity and grades upward into a more dominantly sedimentary series of green tuff and black slate (see section on p. 247), which are unconformably overlain by the conglomerate, slate, and graywacke described on pages 381–382 as probably Lower Cretaceous.

The finer-grained tuff that overlies the breccia is composed, at least in part, of water-laid material, with which are intercalated black slate and thin beds of crystalline limestone. The black slate is a typical clay slate having a well-developed cleavage, with bedding planes discernible in places. The slate is plainly conformable with the green tuff.

Age and correlation.—The age determination of the greenstone and slate rests upon rather slender paleontologic foundation. The collections from Bostwick Inlet were submitted to T. W. Stanton, who stated that lots 9528 and 9529 are "probably Upper Jurassic or possibly Lower Cretaceous" and that lot 9530 is "not sufficient for determining age, but probably from the same formation as 9528 and 9529."

These fossils were collected from the west coast of Bostwick Inlet about half a mile south of the localities at which the Triassic and doubtful collections were made. They were found in sedimentary beds apparently interbedded with the volcanic breccia and overlying the Triassic sediments, but the relations are somewhat obscured by the gravel covering. The localities are listed below.

9528 (15 ACh 104). West coast of Bostwick Inlet 1½ miles south of head of inlet. Thin limestone beds which, together with slate and graywacke, are interbedded with andesitic greenstone. Theodore Chapin, 1915. *Aucella.*

9529 (15 ACh 105). West coast of Bostwick Inlet 500 feet south of 9528. Between the two localities the beds are closely folded and partly concealed, but the beds containing 9529 appear to underlie those containing 9528. Both are interbedded with andesitic greenstone. Theodore Chapin, 1915. *Aucella.*

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[26] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo Islands, Alaska; U. S. Geol. Survey Prof. Paper 120, pp. 95–97, fig. 11, 1918.

9530 (15 ACh 106). West coast of Bostwick Inlet 1,500 feet south of 9529. Andesite flows apparently lower than 9529. Theodore Chapin, 1915. *Pecten.*

9532 (15 ACh 113). Cove 2 miles north of Dall Head, 300 yards southeast of north end of cove. Fossils contained in limestone which was regarded in the field as interbedded with black slate that contains Upper Triassic fossils. (See U. S. Geol. Survey Prof. Paper 120, p. 93, 1918.) Theodore Chapin, 1915. *Aucella?*

UPPER JURASSIC (?) ROCKS OF PRINCE OF WALES ISLAND

The Upper Jurassic may be represented by some andesitic lava flows interstratified with volcanic tuff, conglomerate, and graywacke, having an aggregate thickness of probably about 1,000 feet, which F. E. and C. W. Wright[27] observed at several localities in the southern part of Prince of Wales Island and assigned to the "Jura-Cretaceous(?)." These rocks were described as follows, and a very similar description was repeated by C. W. Wright[28] in a later publication.

> On the southern end of Prince of Wales Island is a succession of andesitic flows, conglomerates, and tuffs, which grade into a series [possibly Lower Cretaceous; see p. 382] of graywackes or indurated sandstones. These have been considered Mesozoic because of their structural and petrographic relations to the older rocks. In this complex, basaltic and andesitic flows are intercalated with the tuffaceous beds, and both flows and tuffs alternate with the sedimentary slates, graywackes, and conglomerates. They are readily distinguished from the greenstones by the wide difference in composition and texture of the interstratified beds and by their predominant reddish color. A fine, compact green tuff is usually overlain by an andesitic lava with numerous large phenocrysts, which in turn is overlain by a basaltic lava or a red lava conglomerate. The greenstone beds, on the other hand, vary little in composition and where massive, augite crystals form the phenocrysts.
>
> On the south end of Prince of Wales Island the andesitic flows and conglomerates overlie at several points the eroded surfaces of granitic intrusive masses, and numerous dikes of the andesite intrude these older granites. Pebbles and fragmentary masses of the granite were observed in the tuffaceous conglomerates, showing clearly that the andesites are younger than these masses of granitic rock. The granites at this point were more altered and contained more shearing planes than are usual in the Coast Range intrusives, and they may represent a batholith intruded before or during the earliest stages of the period of the Coast Range granitic invasion.

SANDSTONE AND VOLCANIC ROCKS OF WINDFALL HARBOR

The rocks on Windfall Harbor, which is on the west shore of Seymour Canal, on Admiralty Island, were mapped by Wright[29] as "Paleozoic, probably chiefly Carboniferous limestones and

[27] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 34, 58, pl. 1, 1908.

[28] Wright, C. W., Geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 87, pp. 19–20, pl. 1, 1915.

[29] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pl. 33, 1906.

schists," but no description was given. The limestone on the east coast of Admiralty Island includes both Permian and Upper Triassic beds. The only evidence of Jurassic rocks on Admiralty Island was yielded by some fossils which Edwin Kirk obtained in 1918 from sandstone interstratified with volcanic sediments on the north shore of Windfall Harbor. The following statement concerning these fossils was submitted by T. W. Stanton:

10170. North shore of Windfall Harbor, east side of Admiralty Island Sandstone interstratified with volcanic sediments. Fragments of a large coarsely ribbed *Pecten*. Probably Jurassic.

TREADWELL SLATE AND DOUGLAS ISLAND VOLCANIC GROUP OF THE JUNEAU DISTRICT

Historical review.—The supposed Upper Jurassic rocks of the Juneau district, which have been called by Eakin and Spencer[30] the Treadwell slate and the Douglas Island volcanic group, are the upper part of the rocks which Spencer[31] earlier described and represented on his general geologic map as the "slate-greenstone band." On his detailed geologic map[32] they were represented as the "black slate," "alternating slates and greenstones," and "greenstones" of Douglas Island. A belt of rocks which occurs throughout Glass Peninsula, on Admiralty Island, and which seems to be the southern extension of the Treadwell slate and the Douglas Island volcanic group was described by Wright[33] as "Paleozoic, probably chiefly Carboniferous slates and greenstones." The Treadwell slate and the Douglas Island volcanic group are also part of the rocks which Knopf[34] grouped in a southern extension of the "Berners formation" and greenstone of the Eagle River district.

Stratigraphic description.—The Treadwell slate (see section on p. 247) consists of black clay slate with some conglomerate and considerable graywacke. Its thickness is probably about 7,000 feet. Apparently it comprises the oldest rocks on Treadwell Island, and it is supposed to overlie the Thane volcanic group, but it has not been observed in direct superposition, as Gastineau Channel separates the formations.

The Douglas Island volcanic group which overlies the Treadwell slate with apparent conformity (see section on p. 247), consists of melaphyre flows, tuff, and agglomerate having a thickness of possibly 15,000 feet.

[30] Eakin, H. M., and Spencer, A. C., Geology and ore deposits of Juneau, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[31] Spencer, A. C., The Juneau gold belt, Alaska: U. S. Geol. Survey Bull. 287, pp. 16–18, pl. 37, 1906.

[32] Idem, pl. 4.

[33] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pp. 141–142, pl. 33, 1906.

[34] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pl. 5, 1912.

Age and correlation.—No fossils have been found in the Treadwell slate or in the Douglas Island volcanic group. Their apparent position above the Thane volcanic group indicates that they are younger than Triassic and probably younger than Lower or Middle Jurassic. Their general position along the southern extension of the supposed Upper Jurassic rocks that have been included in "Berners formation" is suggestive of Upper Jurassic age. Their volcanic character, together with the fact that volcanic rocks are not known in the Cretaceous of Alaska, indicates that at least the Douglas Island volcanic group is either pre-Cretaceous or post-Cretaceous. The Treadwell slate and the Douglas Island volcanic group are therefore referred tentatively to the Upper Jurassic, but it must be admitted that the evidence for this age assignment is very far from conclusive.

"BERNERS FORMATION"

Historical review.—The "Berners formation" was named and defined by Knopf as including "an interstratified series of slates and graywackes well exposed on both shores of Berners Bay." The original description [35] includes an account of the general character and distribution of the formation, a rather detailed petrographic description, and a discussion of the age and correlation, in which there is a statement furnished by Knowlton concerning the character and probable age of the fossil plants. The occurrence of the formation was mapped in detail within the small area covered by Knopf's report. Knopf assigned the formation, on the basis of Knowlton's determination of some fossil plants found within it, to the Jurassic or Lower Cretaceous and suggested, on his own authority, an approximate correlation with the Lower Cretaceous *Aucella*-bearing rocks of Admiralty Island.

The supposed southern extension of the "Berners formation" from Berners Bay to the north end of Gastineau Channel has also been described and mapped in detail by Knopf.[36] This account includes a description of the rocks, a detailed petrographic description, and a discussion of age and correlation. The determination of age was based wholly upon the collection of fossil plants from Berners Bay, described in the report cited above. The discussion of correlation has been misinterpreted as containing a definite statement to the effect that there is no doubt concerning the identity of the "Berners formation" with the Lower Cretaceous *Aucella*-bearing beds of Pybus Bay. This statement was intended,[37] however,

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[35] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, pp. 12–13, 14–17, pl. 2, 1911.

[36] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pp. 13–14, 15–18, pls. 2, 5, 1912.

[37] Oral statement by Adolph Knopf.

to mean only that in Knopf's opinion the "Berners formation" is identical with the slate, graywacke, and conglomerate at Point Young, which Wright[38] correlated with the Lower Cretaceous rocks at Pybus Bay. In the writer's opinion the latter correlation is based upon very scanty evidence (see p. 377) and probably is altogether incorrect.

The "Berners formation" as described and mapped by Knopf included part of the rocks which had previously been described and mapped by Spencer[39] as the "slate-greenstone band" and which had been considered Carboniferous because they were supposed to be the northern extension of the fossiliferous Carboniferous rocks of Taku Harbor.

Knopf included also in the "Berners formation" some of the rocks at the north end of Admiralty Island which Wright[40] described as "slates and greenstones" and considered "Paleozoic, probably chiefly Carboniferous."

The rocks that were described by Knopf[41] in the report on the Eagle River district under the heading "Volcanic rocks" and were mapped as "augite melaphyre"[42] and "greenstone"[43] were regarded as approximately of the same age as the "Berners formation."

The schist that occurs in a belt east of the "Berners formation," between it and the main belt of the Coast Range granitic rocks, was described and mapped by Knopf[44] as a metamorphic phase of the "Berners formation." These rocks were previously described by Spencer[45] as the "schist band." The writer believes that they are probably chiefly Paleozoic, though they may include some infolded Triassic beds (see section on p. 247).

Knopf[46] has also suggested that the graywacke, slate, and conglomerate of the western shores of Chichagof and Baranof Islands may possibly be correlated with the "Berners formation."

Stratigraphic description.—The "Berners formation" consists chiefly of slate and graywacke but includes some interbedded lava and tuff. Part of the graywacke beds are slightly conglomeratic.

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38 Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, p. 143, pl. 33, 1906.

39 Spencer, A. C., The Juneau gold belt, Alaska: U. S. Geol. Survey Bull. 287, pp. 16–18, pls. 4, 37, 1906.

40 Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pp. 141–142, pl. 33, 1906.

41 Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pp. 13–14, 18–20, 1912.

42 Idem, pl. 2.

43 Idem, pl. 5.

44 Idem, pp. 14, 20–23, pls. 2, 5.

45 Spencer, A. C., The Juneau gold belt, Alaska: U. S. Geol. Survey Bull. 287, p. 16, pls. 4, 37, 1906.

46 Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, pp. 13–14, pl. 1, 1912.

The original definition of the formation by Knopf[47] includes the following general description:

A sedimentary formation consisting predominantly of slates and graywackes occupies the largest part of the Berners Bay area. Some basaltic greenstones and quartz porphyry schists are associated with it but are of small importance. The slates comprise in the main highly cleaved black clay slates but include some of green and to a less extent some of red color. The graywackes are intimately interstratified with the slates in beds ranging from a few inches to 8 feet or more in thickness and are commonly of a gray or greenish-gray color. They are roughly schistose and in the thicker beds nearly massive.

In places the graywackes constitute the bulk of the formation and comprise a thick succession of heavy beds separated only by thin beds of slate. This massive development of graywacke is particularly well shown toward the south end of the peninsula.

The southern extension of the "Berners formation" was described by Knopf[48] as follows:

The most important rocks in the region are an interstratified series of clay slates and graywackes which have been named the Berners formation because they are typically exposed at Berners Bay. Rocks of volcanic origin, usually known as greenstones, are also included in the formation, but the larger areas underlain essentially by the greenstones, are separately shown on the geologic map under an appropriate symbol. Toward the northeast the slates and graywackes grade into schists, which are also shown under a separate symbol. The Berners formation forms a long belt trending northwest and southeast, which contains nearly all the mineral deposits of the region.

At Berners Bay the graywackes are intimately interstratified with the slates. The beds of graywacke are not persistent along the strike but are lenticular and interdigitate with the slates. Cross-bedding is finely developed at some places, and some beds are slightly conglomeratic, containing small well-rounded pebbles. The graywackes are massive and do not show the cleavage characteristic of the associated argillite strata.

Toward the south the graywackes become less abundant, and in the territory south of Eagle River they are comparatively scarce. At Auke Bay they are practically absent and the rocks consist almost wholly of fissile black clay slates, which are of roofing-slate quality, unlike those at any other locality in the gold belt. The maximum thickness of individual strata of graywacke, so far as observed, is 80 feet.

The thickness of the "Berners formation" has never been measured, and it is probable that no accurate estimate can be made, because of the intense deformation that the rocks have undergone. The slaty rocks of Douglas Island, which Knopf correlated with the "Berners formation," were considered by the Wrights[49] as possibly having a thickness of 3,000 or 4,000 feet.

Age and correlation.—Some fossil plants were collected from the "Berners formation" by Adolph Knopf on the east side of Berners

[47] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, pp. 14–15, 1911.

[48] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pp. 15–16, 1912.

[49] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, p. 35, 1908.

Bay just north of Sawmill Cove. The rocks at the fossil locality, according to Knopf,[50]

> consist of an interdigitating series of thick lenses of graywacke and argillite standing on edge. The graywackes show crossbedding, and the argillites are ripple marked. The argillaceous rocks are, as a rule, too highly cleaved to have retained the imprints of leaves, which are now commonly represented by graphitized flakes. Leaf-bearing beds seem to be scarce, and the best fossils collected were obtained from a roughly schistose argillite which was gashed by quartz veinlets.

These fossil plants were examined by F. H. Knowlton,[51] who discussed them as follows:

> This material is very difficult to study, for practically all traces of nervation are absent, and dependence must be placed on outline, which has obviously been more or less modified by pressure. With these limitations in mind, I think I have been able to demonstrate the presence of *Taeniopteris*, *Asplenium* or *Dicksonia*, *Thinnfeldia?*, and possibly another fern something like *Dryopteris*.
>
> The choice appears to lie between Jurassic and Lower Cretaceous, and if what has been supposed to be *Taeniopteris* is really such the odds favor the former. I have not found anything that can be identified as a dicotyledon, which also is favorable to the probability of its being Jurassic. Although the evidence as adduced is not very strong and the identifications are tentative, it seems most probable that they are of Jurassic age.

The following statement on the same material has also been submitted by Knowlton:

> The specimens are very small, almost devoid of nervation, and obviously more or less distorted by pressure. The specimens I said might be *Taeniopteris* have nothing but the midrib preserved or possible faint traces of lateral nerves. Without some positive notion of the lateral nerves it is impossible to distinguish this genus from *Pterophyllum*, *Nilssonia*, etc. It is not of much value as it stands.
>
> Another specimen, identified in the first report as possibly *Asplenium* or *Dicksonia*, with wider experience I should now incline to call *Onychiopsis*, close to and perhaps identical with *O. mantelli*, but it is obscure as to outline and without a trace of nervation. I therefore hesitate to say it is *Onychiopsis*, though it certainly does look like it.
>
> The scrap referred to as *Thinnfeldia?* looks also like some forms of *Thyrsopteris*, but it is without nervation and hence very uncertain.
>
> There are some fragments that suggest *Cladophlebis*, but I can't be certain about them.
>
> So much for the things themselves: What can be said with reasonable safety regarding their age indications? Obviously, if we can not determine the genera, we are not in position to interpret their stratigraphic value with accuracy. However, I will go so far as to say that they are, in my opinion, undoubtedly Mesozoic. There is not a thing that could be as old as the Paleozoic. If I have been anywhere near correct in identifying them, the choice must still lie between Lower Cretaceous and Upper Jurassic. They

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[50] Knopf, Adolph, Geology of the Berners Bay region, Alaska: U. S. Geol. Survey Bull. 446, p. 17, 1911.

[51] Idem, p. 17.

might well enough be Upper Jurassic, but I do not think they can be older than Jurassic.

Some fossils were also collected by Theodore Chapin, concerning which the following statement was made by G. H. Girty:

15 ACh 310. Locality, Jualin wharf, Berners Bay. Graywacke float. It is not believed that this rock traveled far, for it is similar to the rock in place along the coast—the graywacke of the "Berners formation." This collection contains a few fossils in a fragmentary condition, as follows:

Some impressions that suggest either graptolites or fenestelloid Bryozoa. Mr. Kirk showed these fossils to Mr. Ulrich, who states that they belong to the genus *Pinnatopora* (one of the Fenestellidae). If the fossils are graptolites the age of this lot would be Cambrian or Ordovician. If they belong to the genus *Pinnatopora* the age would be Devonian or Carboniferous.

Besides these there are impressions that might be external molds of the dorsal valve of a *Derbya* or *Schuchertella*, another impression that suggests some species of *Aviculipecten*, and part of a spirally ribbed coiled shell that might be either a cephalopod or a gastropod, according to the character of the missing parts of the fossil.

So far as I can see you have a free hand in making this lot anything in the Paleozoic except Cambrian, with the probabilities, however, in favor of Carboniferous (Mississippian?).

The rocks heretofore mapped as the "Berners formation" are now divided by Eakin and Spencer [52] into several mapped units, of widely different ages, so that the name has ceased to be a useful stratigraphic term.

GRAYWACKE OF CHICHAGOF AND BARANOF ISLANDS

Historical review.—A belt of graywacke, slate, and conglomerate that extends along the west coast of Chicagof and Baranof islands includes some rocks which are probably Jurassic. The first description of any of these rocks, according to Becker,[53] was given by Hoffman,[54] who stated that the rocks in the vicinity of Sitka consist of graywacke and slate. Becker [55] gave a description of the petrographic character and a discussion of the origin and age of some of these rocks, which he called "pyroclastic diorite" but which all other observers have regarded as graywacke. These rocks have been described briefly by Brooks, who tentatively assigned them first to the Tertiary [56] and afterward to the Mesozoic.[57] Emerson [58] gave a

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[52] Eakin, H. M., and Spencer, A. C., Geology and ore deposits of Juneau, Alaska: U. S. Geol. Survey Bull. — (in preparation).

[53] Becker, G. F., Reconnaissance of the gold fields of southern Alaska, with some notes on general geology: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, p. 43, 1898.

[54] Hoffman, F., Geognostic observations collected on a journey around the world in 1829.

[55] Becker, G. F., op. cit., pp. 44–47.

[56] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska, with an introductory sketch of the geology of southeastern Alaska: U. S. Geol. Survey Prof. Paper 1, p. 26, 1902.

[57] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 227, 1906.

[58] Emerson, B. K., General geology: Alaska, vol. 4, pp. 47–48, Harriman Alaska expedition, 1904.

brief description of tuffaceous graywacke near Sitka, which he referred to the Vancouver series. These rocks were mentioned briefly by the Wrights,[59] who referred them to the "Permian or Upper Carboniferous" and who casually spoke of them, apparently unintentionally, as the "Sitka series."[60] These rocks were described at greater length by Knopf,[61] who suggested that they may lie unconformably on the supposed Carboniferous greenstone and may perhaps be correlated with the "Berners formation." A much more detailed description of these rocks has been given by Overbeck,[62] who found fossils that are probably Upper Jurassic.

Stratigraphic description.—The Upper Jurassic rocks of the west coast of Chichagof Island include graywacke, slate, argillite, conglomerate, and greenstone. Graywacke is the prevailing rock type, the other rocks occurring in relatively small amounts. The pebbles in the conglomerate consist of graywacke, sandstone, chert, light-colored fine-grained igneous rock, and limestone. The series is apparently very thick, possibly many thousand feet, but no estimate of the thickness was made by Overbeck. The Wrights estimated its thickness at 3,000 feet, more or less. The graywacke is underlain by undifferentiated metamorphic rocks, which include sheared conglomerate, limestone, argillite, tuff, lava, and schist. These metamorphic rocks, according to Overbeck, are probably of different ages and may perhaps be correlated with the Upper Triassic or early Jurassic of Gravina Island. The graywacke appears to be structurally conformable with the underlying rocks, but as it has not been so much metamorphosed, an unconformity may be present.

Age and correlation.—The best evidence on the age of the graywacke of Chichagof Island was obtained from two small lots of invertebrates collected by R. M. Overbeck in 1917, concerning which T. W. Stanton made the following statement:[63]

10147 (17AOF7). First prominent bight on southwest side of Slocum Arm, 3 miles southwest of Falcon Arm. *Aucella* sp. related to *A. fischeriana* (D'Orbigny); *Belemnites* sp., fragments of a small slender form.

10148 (17AOF8). Second prominent bight on southwest side of Slocum Arm, 5 miles southwest of Falcon Arm. *Aucella* sp., small distorted specimens possibly belonging to two species, one of which may be same as species in 10147.

The form of *Aucella* in these two lots appears to be distinct from those identified as *A. piochi* Gabb and *A. crassicollis* Keyserling in previous collec-

[59] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 35, 56–57, 1908.

[60] Idem, p. 58.

[61] Knopf, Adolph, The Sitka mining district, Alaska: U. S. Geol. Survey Bull. 504, pp. 13–14, 1912.

[62] Overbeck, R. M., Geology and mineral resources of the west coast of Chichagof Island: U. S. Geol. Survey Bull. 692, pp. 100–109, 1919.

[63] Stanton, T. W., cited by Overbeck, R. M., idem, p. 108.

tions from Pybus Bay, Admiralty Island. The present collections are believed to be of Upper Jurassic age. It should be remembered, however, that the distinction between Jurassic and Lower Cretaceous on the basis of *Aucella* alone is not always safe. It is possible that all the *Aucella*-bearing rocks of southeast Alaska may belong in the same series.

Additional evidence that the graywacke of Chichagof Island is Jurassic rather than Cretaceous is found in the presence of interbedded volcanic strata and in the absence of pebbles of granite in the conglomerate.

ARCTIC SLOPE

GENERAL FEATURES

The Jurassic rocks of the Arctic slope of Alaska include a marine shale, which is well developed in the valleys of Canning and Sadlerochit Rivers, where it has been described as the Kingak shale, and which probably occurs also near the Canadian boundary, where fossils have been obtained that apparently represent part of the fauna of the Kingak shale. The Jurassic rocks of the Arctic slope are noteworthy as being the only marine Jurassic rocks known north of the Alaska Range and as containing a Jurassic fauna of a type that is known elsewhere in Alaska only in the Kialagvik formation of the Alaska Peninsula.

The Kingak shale of the Canning River district is probably overlain by other marine and coal-bearing strata, described as the Ignek formation, which may be of Jurassic age but the exact horizon of which is much in doubt. This formation is here described as possibly Jurassic, although it may be either Jurassic or Cretaceous.

It should be noted that these Jurassic beds of the eastern part of the Arctic slope, like the Triassic beds of the same region, are apparently absent farther west in the Colville Valley, where Lower Cretaceous *Aucella*-bearing rocks, which are absent in the Canning River and international boundary districts, have transgressed upon or have been faulted against the lower Carboniferous limestone.

MIDDLE OR LOWER JURASSIC

KINGAK SHALE

Historical review.—An interesting occurrence of supposed Middle or Lower Jurassic rocks has been found by E. de K. Leffingwell in the valleys of Sadlerochit and Canning Rivers, 90 and 120 miles west of the international boundary. These rocks have been described[64] as the Kingak shale by Leffingwell, whose account of the formation includes a description of its occurrence, character, and thickness and

[64] Leffingwell, E. de K., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, pp. 103, 119–120, pl. 2, 1919.

a discussion of its age and correlation. Statements by T. W. Stanton and Frank Springer concerning fossils collected by Leffingwell are quoted.

Stratigraphic description.—The Kingak shale was named by Leffingwell from its type occurrence at Kingak Cliff on Sadlerochit River, and was described [65] as follows:

The Kingak shale, which consists of about 4,000 feet of black shales, overlies the Shublik formation of Triassic age and probably underlies the Ignek formation of Jurassic (?) age. It is apparently conformable in bedding with the Shublik formation, but nothing is known of the upper contact. The formation named is confined to the shales which contain the fauna that is listed below. The Kingak shale has been identified at only one locality, Kingak Cliff, near camp 263, at the southeast end of Sadlerochit Mountains.

Age and correlation.—The fauna of the Kingak shale, as now known, is restricted to the five species represented in the table on page 264. These fossils apparently occur generally and abundantly distributed throughout the lower 1,500 feet of the formation. The higher shale has not thus far yielded any fossils, but no exhaustive search was made for them.

The most significent members of this fauna are the ammonites, which are referred to characteristic Liassic and Lower Oolitic genera and which include forms that are very closely related to if not identical with, species that have hitherto been found only in the Middle (?) Jurassic rocks of the Alaska Peninsula, described on pages 186–191 as the Kialagvik formation, which several European paleontologists have classified as Upper Liassic (Toarcian) but which Stanton considers (p. 189) Middle Jurassic. Stanton's statement regarding the ammonites from the Kingak shale is as follows:

The collections from localities 110 and 114 all belong to a single fauna, and the ammonites in them indicate that the horizon represented is probably about the same as the exposures on Kialagvik [Wide] Bay, Alaska Peninsula, which have yielded an ammonite fauna described by White and referred to the Lower Jurassic (upper Lias) by Hyatt and Pompeckj.

The pelecypod identified by Stanton as *Inoceramus* cf. *I. lucifer* Eichwald is closely related to if not identical with a species that has been regarded as characteristic of the Tuxedni sandstone of Cook Inlet. The Tuxedni sandstone, which is described on pages 140–158, is Middle Jurassic and, according to Stanton, "certainly included at least part of the Lower Oolite."

The crinoid, which was not associated with the other fossils, was identified by Frank Springer, who said of it (and of the similar crinoids from Firth River, described on p. 265):

While this material is not sufficient for any accurate specific determination or description, there is enough to show that it clearly belongs to the true

[65] Leffingwell, E. de K., op. cit., p. 119.

Pentacrinus (= *Extracrinus* Austin of DeLoriol, P. H. Carpenter, and other authors), of the Lower Jurassic of England and continental Europe, and of the type of *P. subangularis* Miller, from the Middle Liassic of Lyme-Regis, England, and Boll, Holzmaden, and other localities in Wurtemburg, Germany. In default of more perfect specimens it may be referred to that species.

The specimens No. 12 Md. 82 (from a tributary to Overthrust Creek, 1¾ miles above the mouth and about 8 miles west of the 141st meridian) consist of column and arm fragments of very large size. The matrix is highly ferruginous, with much oxidation on the surface, so that the preservation of the specimens is poor. The material from Black Island, Canning River, brought in by Mr. Leffingwell, is of very different character and is of great interest. It consists of part of a set of arms belonging to a very large individual, in exquisite preservation. The matrix and mode of deposition are very similar to those of the *Pentacrinus* beds at Lyme-Regis, and the condition of the specimen indicates that it was part of a considerable colony, of which a large number of individuals were embedded together.

The specimens from the two localities, which I understand are upward of 100 miles apart, agree in their uniformly large size, which is greater than that of those usually found at Lyme-Regis, but not than that of specimens from the Wurtemburg localities, which are sometimes even larger.

So far as I know this is the first discovery of remains of *Pentacrinus*, with the exception of isolated stem joints, yet found in American rocks, and it is interesting to note that a specimen of the same genus and type has recently been found in the Dutch East Indies, thus showing the great geographical range of this genus.

Fossils from the Kingak shale [a]

	110	110E	114a	114b	Bl. I.
Pentacrinus cf. P. subangularis Miller					b
Inoceramus cf. I. lucifer Eichwald	a	a	a	a	
Hammatoceras cf. H. howelli (White)			a		
Harpoceras whiteavesi (White)	a				
Harpoceras	a				

[a] a, Identified by T. W. Stanton; b, identified by Frank Springer.

110. Sadlerochit River, cut on north side running northeast from camp 258, about 2,400 feet northeast (magnetic) from camp at edge of bank. Friable black shale with pyrite concretions. E. de K. Leffingwell, 1910–1912.

110E. Talus and wash, Sadlerochit River. E. de K. Leffingwell.

114a. Sadlerochit River, half a mile up the creek from camp 263. Fossils mostly from concretions in black shale at foot of exposure. E. de K. Leffingwell, 1910–1912.

114b. Sadlerochit River, about 200 to 300 yards below camp on north side of river or about half a mile down the creek from 114a. About 1,500 feet above 114a. E. de K. Leffingwell, 1910–1912.

Bl. I. Black Island, Canning River, opposite Mount Coplestone. Collected by an Eskimo, supposedly from a small exposure of black shale. E. de K. Leffingwell, 1910–1912.

CRINOID BED OF FIRTH RIVER

Lower Jurassic rocks are probably present in the Firth Valley near the international boundary. This horizon has been recognized

from some fossils collected by A. G. Maddren, but the rocks containing this supposed Lower Jurassic fauna have not been differentiated from the Upper Triassic rocks,[66] which they closely resemble and with which they are intimately associated both stratigraphically and structurally. These supposed Lower Jurassic rocks were not described by Maddren, but a brief reference to their occurrence was made by Leffingwell.[67]

The supposed Lower Jurassic rocks of Firth River have been recognized only in a thin ferruginous stratum occurring in the midst of an area of Upper Triassic shale and limestone on a tributary of Overthrust Creek about 8 miles west of the international boundary, in latitude 68° 56′ 10″. The exposure of Triassic and Jurassic beds, according to Maddren, apparently includes about 1,000 feet of strata composed chiefly of dark shale that is too much crumpled to permit a deciphering of the stratigraphy and structure. The supposed Lower Jurassic fauna consists wholly of crinoids, which were recognized only in a highly ferruginous calcareous bed, 3 to 5 inches thick, apparently interstratified with beds of dark limestone containing the Upper Triassic fossils described on page 100–103.

These crinoids have been studied by Frank Springer, whose statement concerning them is quoted on pages 263–264. In commenting upon the fossils supposed to have been obtained at or near this locality, Stanton said:

> While the crinoids suggest Lower Jurassic age, all the other invertebrates above listed [see p. 102] indicate Upper Triassic. . The crinoids were not actually intermingled with the other fossils, and this fact suggests the possibility that they came from a different formation. A few fragments of fossiliferous Carboniferous limestone differing in color and other characters from the limestone containing the Triassic fossils were in this lot when it was received.

A crinoid which, according to Springer, probably belongs to the same species was obtained by Leffingwell on Canning River, about 120 miles west of this locality. This occurrence is described on pages 263–264. The crinoid from Canning River apparently occurs in a formation that has yielded Lower or Middle Jurassic ammonites.

JURASSIC (?)

IGNEK FORMATION

Historical review.—Some rocks of probable Jurassic age but of indeterminate position within the Jurassic were discovered by E. de K. Leffingwell on Canning and Marsh Rivers about 90 to 120 miles west of the international boundary. These rocks have been de-

[66] Maddren, A. G., Geologic investigations along the Canada-Alaska boundary: U. S. Geol. Survey Bull. 520, pp. 312–313, 1912.
[67] Leffingwell, E. de K., op. cit., p. 120.

scribed as the Ignek formation by Leffingwell,[68] whose account includes detailed descriptions of the rocks exposed at various places and a discussion of their age in which statements by Stanton and Knowlton concerning the fossils are quoted.

Stratigraphic description.—The Ignek formation as described by Leffingwell [69] was named from its typical occurrence on Ignek Creek, on the south side of Red Hill, at the west end of the Sadlerochit Mountains. This formation occurs at both ends and probably along the north front of these mountains. It "consists of about 2,500 feet of black shale with coal or 'red beds' and subordinate sandstone members." These rocks probably overlie the Lower (?) Jurassic Kingak shale, although there is some doubt about this, as the two formations have not been observed in the same district. The top of the Ignek formation has not been recognized, and younger rocks are not known in this region. The section at the type locality was recorded by Leffingwell as follows:

Section of Ignek formation on the south side of Red Hill

	Feet
1. Blue-gray fine-grained sandstone	200
2. Black shale, with red bed near the top. The fossils of lot 3 were obtained near the middle	1,500
3. Unexposed	400
4. Gray sandstone, weathering yellow	100
5. Unexposed	400

The red beds near the top of this section are considered by Leffingwell to "mark the former existence of coal" that has been burned.

Near the head of Marsh Creek, at the east end of the Sadlerochit Mountains, is a poorly exposed and complexly folded section containing sandstone and shale that overlie some red beds like those at Red Hill. The sandstone yielded the fossils of lots 117A and 118A.

On the west side of Canning River, opposite Mount Coplestone, is sandstone from which the fossils of lot 100 were obtained. This sandstone is probably the same as that at the head of Marsh Creek.

Age and correlation.—The known fossils of the Ignek formation as represented in the following table include 24 or more undetermined species of marine invertebrates, mostly mollusks, from four localities, and some fossil wood. The fauna of three of these localities (100, 117a, and 118a) is connected by a common species of *Astarte*. The fourth locality (No. 3) has no species and only one or two genera in common with any of the other three localities. It is possible, therefore, that two entirely distinct faunas are repre-

[68] Leffingwell, E. de K., The Canning River region, northern Alaska: U. S. Geol. Survey Prof. Paper 109, pp. 103, 120–125, pl. 2, 1919.

[69] The description here given consists of an abstract prepared with Mr Leffingwell's assistance from the manuscript of the detailed report cited above.

sented. The fossils of lot 3, which came from the black shale below the coal beds, are regarded by Leffingwell as the typical fauna of the Ignek formation. The fossils from the other three localities, which came from the sandstone above the coal beds, should possibly be regarded as a distinct fauna representative of a higher formation. However, as the fossils from all these localities are of doubtful relationships, and as no striking and essential differences have been recognized, they will be tentatively considered as constituting a single fauna.

These rocks are shown to be post-Triassic, both by their stratigraphic position and by the occurrence of such genera as *Yoldia*, *Inoceramus?*, *Pholadomya?*, *Goniomya?*, *Cyprina?*, *Astarte*, and *Belemnites?*. The occurrence of *Spiriferina?*, *Inoceramus?*, *Pleuromya*, *Goniomya?*, *Homomya*, and *Belemnites?* shows that they are not younger than Cretaceous. The presence of *Spiriferina* would seem to indicate that they are pre-Cretaceous, and the presence of *Yoldia* would seem to indicate that they are post-Jurassic. It consequently is impossible, on the basis of the data now available, to determine their age more closely than Jurassic or Cretaceous.

In regard to the fossils from locality 3, Stanton[70] said:

> This rather poorly preserved collection is puzzling because of its lack of relationship to any other Alaskan fauna known to me and because of the absence of characteristic types. It is probably Mesozoic and may be Jurassic.

Concerning locality 100, he said: "This puzzling collection of fairly well preserved Mollusca is presumably of Jurassic age, but it seems to have no species in common with any of the known Jurassic or other Mesozoic faunas of Alaska." The *Astarte* in lots 117a and 118a is the same species as that in lot 100, according to Stanton, who said: "Nos. 117a and 118a are probably Jurassic, from about the same horizon as No. 100."

The fossil wood from locality No. 3 has been examined by F. H. Knowlton,[71] who said of it:

> I have examined the thin sections of this material and find it to be coniferous wood with unusually small wood cells or tracheids. In the radial section the pits on the tracheids are found to be nearly circular in outline and disposed in a single vertical row. The pores or slits in the pits could not be made out with certainty, nor could markings or pits of any kind be noted on the lateral walls of the medullary rays.
>
> In the tangential section the medullary rays are seen to be arranged in a single series of usually two to four cells, though occasionally there is only one and rarely there may be six or seven.
>
> I do not find any characters which would mark this wood as unmistakably of Paleozoic age, and to the best of my knowledge and belief it is Mesozoic. It is probably to be best regarded as a species of *Araucarioxylon*.

[70] Stanton, T. W., cited by Leffingwell, E. de K., op. cit., p. 124.
[71] Knowlton, F. H., cited by Leffingwell, E. de K., op. cit., p. 125.

Fossils from the Ignek formation [a]

	3	100	117a	118a
Araucarioxylon (wood) [b]	×			
Terebratula?	×			
Spiriferina?	×			
Nucula	×			
Leda	×			
Yoldia	×			
Inoceramus?? (small imprint)	×			
Pecten	×			
Lima?	×			
Modiola (fragment)	×			
Pleuromya			×	
Pleuromya?	×			
Pholadomya? (young shell)	×			
Goniomya? (fragment)	×			
Homomya		×		
Cyprina?		×		
Astarte	×			
Astarte (as in lot 100)		×	×	×
Undetermined pelecypods (two or more genera)	×			
Dentalium??		×		
Pleurotomaria?		×		
Natica		×		
Burtinella	×			
Belemnites? (phragmacones?)		×		

[a] Identified by T. W. Stanton, except as indicated.
[b] Identified by F. H. Knowlton.

3. Canning River, cut on south side of Red Hill, Ignek Valley, about half a mile east of red beds. Very friable black shale, as indicated in section on p. 266. E. de K. Leffingwell, 1908.

100. Canning River, cut on west side of river opposite Shublik Island. Second outcrop of sandstone going north. The fossils are very abundant in a rusty band a few inches thick and are not found elsewhere. Two lots (A and B) were collected from the same bed at two places 50 or 100 feet apart. This sandstone is considered the same as 118a, on Marsh River. E. de K. Leffingwell, 1910–1912.

117a. Marsh River, exposure 50 yards above camp 266, on east side of river. E. de K. Leffingwell, 1910–1912.

118a. Marsh River, cut on northeast side of the river a mile above camp 266, at the first good exposure of sandstone. Fossils from a rusty band. E. de K. Leffingwell, 1910–1912.

SUMMARY

STRATIGRAPHY

LOWER JURASSIC

General sequence.—The Lower Jurassic rocks of Alaska are believed to include a lower sedimentary division, a middle dominantly volcanic division, and an upper sedimentary division. The supposed lowest division comprises the Lower Jurassic calcareous sandstone, shale, and limestone of the Alaska Peninsula. The supposed intermediate volcanic division comprises the Talkeetna formation of the Talkeetna Mountains and Matanuska Valley, the Skwentna group of the Alaska Range, some unnamed lavas and tuffs on Kenai Peninsula and the west coast of Cook Inlet, and possibly

the Thane volcanic group and other breccias, tuffs, and lavas of southeastern Alaska. The supposed upper division of the Lower Jurassic comprises the Kialagvik formation of the Alaska Peninsula and the Kingak shale of the Arctic coast. The assignment of all these rocks to the Lower Jurassic has not, however, been positively established. The Kialagvik formation, the Kingak shale, some of the volcanic rocks of Cook Inlet, and the Thane volcanic group of southeastern Alaska are possibly Middle Jurassic.

The sequence of these rocks within the Lower Jurassic has not been clearly proved either by observed succession or by paleontologic evidence. The sequence that is indicated above and that is shown in the table opposite page 270 represents the writer's opinion, which is based on incomplete and indirect evidence that will be discussed below.

Lower Lias (?) horizon.—The oldest Jurassic rocks of Alaska are believed to be the 2,300 feet of calcareous sandstone, sandy shale, and limestone of the Alaska Peninsula, which lie with apparent conformity on Upper Triassic beds and are overlain by or faulted against Upper Jurassic beds. These rocks have been found only in a small area near Cold Bay. Their equivalent has not been recognized elsewhere in Alaska, but it may possibly be represented by unrecognized beds in or associated with the Lower Jurassic volcanic rocks of Cook Inlet and the Talkeetna Mountains. These rocks have been assigned to the lowest position in the Alaskan Jurassic sequence, because of their apparently conformable position on the Upper Triassic rocks and because the few fossils which they have yielded include ammonites that are suggestive of the Lower Lias.

Talkeetna horizon (Middle Lias?).—The Talkeetna formation of the Talkeetna Mountains and Matanuska Valley is believed to occupy a position in the Lower Jurassic somewhat above the horizon of the basal Jurassic (Lower Lias?) calcareous sandstone, shale, and limestone of Alaska Peninsula. It is composed of lava, agglomerate, and tuff interbedded with sandstone and shale. Its thickness is probably at least 3,000 feet. It contains fossil plants and marine shells. It is probably represented by the tuff, agglomerate, and interbedded marine fossiliferous strata of Seldovia and Port Graham, on Kenai Peninsula, by the basaltic and andesitic lava and tuff of the west coast of Cook Inlet, by the lava, tuff, arkose, chert, and limestone of the Skwentna group of the Alaska Range, possibly by the supposed Lower Jurassic tuffaceous conglomerate near Taral, in the Chitina Valley, possibly by part or all of the Thane volcanic group near Juneau, and possibly by part or all of the lower or Middle Jurassic breccia, tuff, and lava of the Wrangell district and of Gravina Island.

The rocks of the Talkeetna horizon have not been observed in contact with those of the supposed older (Lower Lias?) beds of Alaska Peninsula or with those of the supposed younger Kialagvik formation. Paleontologic evidence of their relation to these formations is also lacking. The Talkeetna formation is tentatively assigned to a position next above the basal Jurassic (Lower Lias?) of Alaska Peninsula, because its fossils include genera that are suggestive of a position fairly low in the Lias, and because neither the fossils nor any known superposition of the rocks on Triassic beds offers any suggestion that these rocks are at the base of the Alaskan Jurassic sequence.

Kialagvik horizon (*Upper Lias ?*).—The writer believes that the youngest Lower Jurassic rocks of Alaska are those of the Kialagvik formation of the Alaska Peninsula and the Kingak shale of the Arctic slope. The rocks of the Kialagvik horizon have not been seen in contact with the supposedly next older rocks of the Talkeetna horizon. The Kialagvik fauna is clearly younger than any fossils that have been found in the Talkeetna formation or in its supposed equivalent on Kenai Peninsula.

The exact relation of the Kialagvik formation to the next younger rocks of the Tuxedni horizon, which are Middle Jurassic, has not been determined. Fossils that are supposed to be representative of the Tuxedni fauna have been found in close geographic association with the rocks of the Kialagvik formation, but there is some doubt as to whether this association implies a transition from the Kialagvik to the Tuxedni beds or the presence of unrecognized areas of the Tuxedni sandstone within the supposed area of the Kialagvik formation. The writer believes that the rocks and faunas of the Tuxedni and Kialagvik horizons will probably prove to be sharply defined and that they may be separated by an unconformity.

MIDDLE JURASSIC

Tuxedni horizon (*Bajocian and Bathonian*).—The undoubted Middle Jurassic rocks of Alaska include the Tuxedni sandstone of the west coast of Cook Inlet and the Matanuska Valley; the Tordrillo formation, which carries the Tuxedni fauna, in the Yentna and Skwentna Valleys; and a tuffaceous slate with the Tuxedni fauna near the mouth of Chitina River. Fossils that occur in the Tuxedni fauna have also been found on the Alaska Peninsula, and it is possible that part of the rocks that have been mapped as belonging in the Kialagvik (Middle? Jurassic) and Shelikof (Upper Jurassic) formations may actually represent unrecognized areas of the Tuxedni sandstone. It is also possible that the Tuxedni horizon may be represented in some of the volcanic rocks of southeastern Alaska, not-

Correlation of Jurassic rocks of Alaska

Age	European classification	Alaska Peninsula	West coast of Cook Inlet	Kenai Peninsula	Alaska Range (Yenta and Skwentna valleys)	Matanuska Valley and Talkeetna Mountains	Chitina Valley	Nutzotin Mountains	Chichagof and Baranof islands	Juneau district	Gravina Island	Canning River and vicinity	Firth River
Upper Jurassic.	Purbeckian.												
	Portlandian.	Naknek formation: Shale, sandy shale, and sandstone; 1,200 feet. Arkosic sandstone; 800 feet.	Naknek formation: Massive sandstone, arkose, and tuff; 3,000 feet.			Naknek formation: Shale, sandstone, and conglomerate with *Aucella* and *Cardioceras*; 1,000 +feet.				Douglas Island volcanic group; melaphyre flows, tuff, and agglomerate. May be post-Jurassic. Treadwell slate; black clay slate with some conglomerate and considerable graywacke. May be post-Jurassic.			
	Kimmeridgian.							Slate, graywacke, and conglomerate with *Aucella*.	Graywacke, slate, and conglomerate with *Aucella*.		Slate and limestone interbedded with tuff and containing *Aucella*.		
	Sequanian or Upper Oxfordian.		Gray shale with some sandstone; *Cardioceras* in lower part; 1,500 feet,									Ignek formation; black shale with coal beds and some sandstone; contains marine "Jurassic or Cretaceous" fossils; position uncertain; 2,500 feet.	
	Argovian or Lower Oxfordian.	Conglomerate (Chisik?); 2,000–3,000 feet.	Chisik conglomerate member; 290–400 feet.			Conglomerate (Chisik?).							
	Callovian.	Shelikof formation: Black shale; 700–1,000 feet. Sandstone with some shale and conglomerate; 4,000–4,700 feet. Shale; 1,500 feet.	Chinitna shale; dark shale with *Cadoceras* in lower part; 2,300 feet.			Chinitna formation; shale, conglomerate, and sandstone with Chinitna fauna; 2,000± feet.							
Middle Jurassic.	Bathonian or Great oolite.		Tuxedni sandstone; sandstone and sandy shale, with some conglomerate and limestone; 1,500 to 3,000 or possibly 8,000 feet.		Tordrillo formation; grit, sandstone, and argillite, with some conglomerate and limestone; includes beds with Tuxedni fauna; 2,000 to 3,000 feet.	Tuxedni sandstone; sandstone, sandy shale with Tuxedni fauna; 1,000± feet.	Tuffaceous slate near mouth of Chitina River with Tuxedni fauna.						
	Bajocian or Inferior oolite.												
Lower Jurassic.	Toarcian or Upper Lias.	Kialagvik formation; sandstone and sandy shale; 500+ feet. (May be partly or wholly Middle Jurassic.)								Thane volcanic group; melaphyre tuff, limestone, tuff, and slate (possibly Lower or Middle Jurassic).	Breccia, tuff, and lava (possibly Lower or Middle Jurassic).	Kingak shale; black shale with fauna of Kialagvik formation and crinoids; several thousand feet. (May be Middle Jurassic).	Dark shale with crinoids; rocks associated with Triassic beds; thickness not known.
	Charmouthian or Middle Lias.		Basaltic and andesitic lava and tuff; 1,000 feet.	Tuff and conglomerate with interbedded marine fossiliferous strata; 1,000 to 3,000 feet.	Skwentna group; lava, tuff, arkose, chert, and limestone; 1,000 to 4,000 feet. Probably Lower Jurassic.	Talkeetna formation; lava, agglomerates, and tuff interbedded with sandstone and shale; 3,000 ± feet. Largely or wholly marine.	Tuffaceous conglomerate near Taral; 500+ feet.						
	Lower Lias.	Calcareous sandstone, sandy shale, and limestone; 2,300 feet.											

ably in the Thane volcanic group and in the "Lower or Middle Jurassic breccias, tuffs, and lavas" of Gravina Island.

The Tuxedni sandstone of Cook Inlet includes sandstone and sandy shale with some conglomerate and limestone. It has a thickness of probably 1,500 to 3,000 feet and possibly 8,000 feet. It is believed to lie unconformably on Lower Jurassic lava and tuffs of the Talkeetna horizon and is overlain with apparent conformity by the Upper Jurassic Chinitna shale. It contains many marine invertebrate fossils and some fossil plants.

The Tuxedni sandstone of the Matanuska Valley includes sandstone and sandy shale that seem to be about 1,000 feet thick, underlain by the Talkeetna formation and overlain by beds that carry the fauna of the Chinitna shale.

The Tordrillo formation of the Alaska Range (Yentna and Skwentna Valleys) is composed of grit, sandstone, and argillite with some conglomerate and limestone. It is 2,000 to 3,000 feet thick. It contains beds that carry the Tuxedni fauna. The Tordrillo formation is believed to lie unconformably on the rocks of the Skwentna group, which is believed to belong at the Talkeetna horizon. Its top and the overlying beds have not been recognized.

The tuffaceous slate near the mouth of Chitina River which contains the Tuxedni fauna is underlain by tuffaceous conglomerate that may be Lower Jurassic. No overlying beds have been seen.

The Thane volcanic group, which is perhaps of Tuxedni age, consists of melaphyre tuff, limestone, and tuff and slate. Melaphyre tuff that may be of the same age has been found in the Wrangell district. Some breccia, tuff, and lava on Gravina Island may also belong at the Tuxedni horizon.

UPPER JURASSIC

General sequence.—The Upper Jurassic rocks of Alaska include beds assigned to three generally recognizable horizons. At the base of the Upper Jurassic is the *Cadoceras* zone of the Chinitna shale and its equivalent, which corresponds to the Callovian of the European classification. Next above the Chinitna is the *Cardioceras* zone, which occurs in the lower part of the rocks that have been described as the Naknek formation of Cook Inlet and which corresponds to the Oxfordian of Europe. At the top of the Upper Jurassic is the upper part of the Naknek formation of the Alaska Peninsula and its probable equivalents, which are characterized by *Aucella* cf. *A. pallasi* Keyserling, *Aucella* cf. *A. bronni* Rouillier, and *Aucella* cf. *A. erringtoni Gabb* and which are believed to correspond to the Kimmeridgian and Portlandian of the European sequence.

Cadoceras zone (*Callovian*).—The oldest Upper Jurassic rocks of Alaska—the Cadoceras zone—include the typical Chinitna shale of

the west coast of Cook Inlet; some shale, conglomerate, and sandstone with the fauna of the Chinitna shale in the Matanuska Valley; and the middle member of the Shelikof formation of the Alaska Peninsula, which consists of sandstone, shale, and conglomerate carrying the Chinitna fauna.

The Chinitna shale of the west coast of Cook Inlet consists of dark shale about 2,300 feet thick. It overlies the Tuxedni sandstone with apparent conformity and is overlain, without known conformity, in some places by unfossiliferous conglomeratic beds (Chisik conglomerate member of Naknek formation) and in others by the shale of the higher *Cardioceras* zone of the Naknek formation. The Chinitna shale contains several species of *Cadoceras*, which are regarded as characteristic of its horizon.

The Chinitna formation of the Matanuska Valley is composed of shale, conglomerate, and sandstone about 2,000 feet thick. It rests conformably on the Tuxedni sandstone and is believed to be overlain conformably by shale of the *Cardioceras* zone and perhaps locally by the equivalent of the Chisik conglomerate member.

The Shelikof formation of the Alaska Peninsula includes three members—shale about 1,500 feet thick at the base; sandstone interbedded with some shale and conglomerate, having a thickness of 4,000 to 4,700 feet, in the middle; and black shale 700 to 1,000 feet thick at the top. The middle member contains the fauna of the Chinitna shale. The lower and upper members have yielded only fossils that are not characteristic of definite horizons. The base of the Shelikof formation has not been clearly recognized. There are some indications that it may rest unconformably on the Kialagvik and basal Jurassic formations, but these supposed basal contacts may be faults. The Shelikof formation is overlain, with apparent conformity, by conglomerate that is supposed to be the approximate equivalent of the Chisik conglomerate member of the Naknek formation of Cook Inlet.

Cardioceras zone (*Oxfordian*).—The next fossiliferous strata above the *Cadoceras*-bearing beds of the Chinitna shade on the west coast of Cook Inlet consist of shale that contain several species of *Cardioceras*. This shale has heretofore been included in the Naknek formation, but inasmuch as *Cardioceras* has been found at only one locality on the Alaska Peninsula, there is some doubt as to whether the shale is represented in the type section of the Naknek formation and as to whether it should be considered part of the Naknek formation. The writer believes that the *Cardioceras*-bearing beds should be excluded from the Naknek formation. *Cardioceras* has also been found at one locality in the Matanuska Valley, in beds which have been referred to the Naknek formation but whose precise position

relative to the other horizon has not been determined. *Cardioceras* has not been found in other Alaskan regions.

The position of the *Cardioceras*-bearing beds on Cook Inlet is perhaps occupied locally by the massive, lenticular, unfossiliferous beds of the Chisik conglomerate member of the Naknek formation, which directly succeeds the Chinitna shale at some localities and is absent or reduced to pebbly sandstone at other localities, notably at the localities near which *Cardioceras* has been found. The Chisik conglomerate is supposed to be represented by conglomerate in the Matanuska Valley and Alaska Peninsula, but the writer suspects that in one or both of these localities the conglomerate may occur at a higher horizon than that of the Chisik conglomerate.

Aucella zone (*Kimmeridgian and Portlandian*).—The rocks of the *Aucella* zone include the major part of the Naknek formation of the Alaska Peninsula; the upper part of the Naknek formation as heretofore described on the west coast of Cook Inlet; the upper part of the rocks in the Matanuska Valley that have been described as the Naknek formation; the slate, graywacke, and conglomerate with *Aucella* cf. *A. bronni* in the Nutzotin Mountains; the graywacke, slate, and conglomerate with *Aucella* cf. *A. fischeriana* (D'Orbigny) of Chichagof and Baranof islands; possibly the Treadwell slate and the Douglas Island volcanic group of the Juneau district; a part of the "Berners formation" of Berners Bay; and possibly the slate, limestone, and tuff containing *Aucella* on Gravina Island.

The Naknek formation of the Alaska Peninsula has been described as including at its base the probable representative of the Chisik conglomerate member of the Naknek formation of the west coast of Cook Inlet, above which is 800 feet of arkosic sandstone, overlain by 1,200 feet of shale, sandy shale, and sandstone. The fauna of the typical Naknek formation, which is characterized especially by several species of *Aucella* related to *A. pallasi* Keyserling, *A. bronni* Rouillier, and *A. erringtoni* Gabb, occurs chiefly if not wholly in the upper shale member.

The rocks on the west coast of Cook Inlet that have heretofore been described as the Naknek formation include 3,000 feet of massive sandstone, arkose, and tuff, underlain by 1,500 feet of gray shale with some sandstone. The lower beds, which contain *Cardioceras* in their lower part, have already been described as the *Cardioceras* zone. The upper beds, which overlie the lower beds conformably, and possibly part but probably not all of the lower beds are believed by the writer to represent the Naknek formation of the Alaska Peninsula.

The Naknek formation of the Matanuska Valley comprises at least 1,000 feet of shale, sandstone, and conglomerate. An undetermined part of these rocks belong in the *Cardioceras* zone. The Naknek rocks of the Matanuska Valley include some beds of conglomerate, which may either represent the Chisik conglomerate or may belong at some higher horizon in the Naknek, probably at the top of the *Cardioceras* zone.

The Naknek is represented in the Nutzotin Mountains by slate, graywacke, and conglomerate containing *Aucella bronni* Rouillier. These beds are believed to be underlain unconformably by Upper Triassic rocks and to be overlain by Lower Cretaceous beds.

The Naknek is probably represented on Chichagof and Baranof Islands by graywacke, slate, and conglomerate containing *Aucella* cf. *A. fischeriana* (D'Orbigny).

In the Juneau district the Naknek may possibly be represented by part or all of the Treadwell slate, which is composed of black clay slate with some conglomerate and considerable graywacke, and of the Douglas Island volcanic group, which is composed of melaphyre lava, tuff, and agglomerate. Neither the Treadwell slate nor the Douglas Island volcanic group has yielded any fossils.

The "Berners formation" of Berners Bay also includes some Upper Jurassic rocks, which probably represent the Naknek formation.

The *Aucella*-bearing slate, limestone, and tuff of Gravina Island, which are underlain by supposed Lower or Middle Jurassic volcanic rocks and overlain by supposed Lower Cretaceous conglomerate, graywacke, and slate, may also belong at the Naknek horizon.

CORRELATION

LOWER JURASSIC

The evidence for the correlation of the Lower Jurassic rocks of Alaska, together with that concerning the other Jurassic rocks of the territory, has already been presented in detail in the description of local sections on pages 133–268. A summary of the correlation of the Jurassic formations of the several Alaskan districts with each other has been given in the table facing page 270. A similar summary of the correlation of the Alaska Jurassic formations with those of other North American regions is given in the table facing this page.

It has been shown on page 268 that the supposed Lower Jurassic rocks of Alaska probably include three formations of different ages, which the writer has designated, in ascending order, basal calcareous sandstone, sandy shale, and limestone of Lower Liassic (?) age; the

Correlation of Jurassic rocks of North America

Age	European classification	Alaska	Graham Island, B. C.[a]	Skeena River, B. C.[b]	Itasyoucou (Dean) River, B. C.[c]	Kamloops district, B. C.[d]	Alberta[e]	Montana[f]	Wyoming, Colorado, and Utah[f]	Humboldt Range, Nevada[g]	Cascade Mountains, Washington[h]	Blue Mountains, Oregon[i]	Western Oregon and northern California[j]	Redding quadrangle, California[k]	Taylorsville region, California[l]	Sierra Nevada, California[m]	Texas[n]	Mexico[o]	Cuba[p]
Upper Jurassic	Purbeckian.												Knoxville group (?) (lower part ?) and Myrtle formation (?) (lower part ?); may be Jurassic or Cretaceous. Dothan formation; sandstone and shale with *Aucella erringtoni*. Galice formation; slate with some sandstone and conglomerate; contains *Aucella erringtoni*.				Malone formation; (limestone with some conglomerate, sandstone, and gypsum.		
	Portlandian.	Naknek formation: *Aucella*-bearing beds.																Marly and phosphatic limestone in Sierra de Mazapil and Santa Rosa.	
	Kimmeridgian.														Foreman formation (exact position doubtful).	Mariposa slate; slate, sandstone, conglomerate, and tuff, with *Amoebocerat* and *Aucella erringtoni*.		Shale and limestone near Mazapil, with *Aucella* and ammonites.	
	Sequanian or Upper Oxfordian.	Naknek formation: *Cardioceras* zone.		Hazelton group; andesitic porphyry and tuff, interbedded with fossiliferous sandstone and shale; probably contains Upper Jurassic (Naknek) and Middle Jurassic (Tuxedni) faunas.							Sandstone, slate, and conglomerate, with *Aucella erringtoni*.				Hinchman sandstone.			Limestone with *Nerinea* near Mazapil; marly limestone in Oaxaca.	Limestone near Viñales, in Pinar del Rio.
	Argovian or Lower Oxfordian.	Naknek formation: Chisik conglomerate member.					Fernie shale; dark shale with *Cardioceras*.	Ellis formation; calcareous shale, sandstone and limestone with *Quenstedticeras* in upper part; Callovian genera in lower part.	Sundance formation; sandstone and shale with *Cardioceras*.										
	Callovian.	Chinitna shale.													Bicknell sandstone.				
Middle Jurassic	Bathonian or Great oolite.	Tuxedni sandstone.	Yakoun formation; basaltic agglomerate, lava, and tuff and tuffaceous sandstone with Tuxedni fauna.		"Porphyrite series"; porphyry and tuff interbedded with sediments containing Tuxedni fauna.														
	Bajocian or Inferior oolite.					Nicola series; upper part comprising limestone with Lower or Middle Jurassic fossils, underlain by Triassic volcanic rocks.								Potem formation; shale, sandstone, and tuffaceous conglomerate.	Mormon sandstone. Thompson limestone.			Marly beds with *Stephanoceras* in Oaxaca.	
Lower Jurassic	Upper Lias or Toarcian.	Kialagvik formation. (May be partly or wholly Middle Jurassic.)										Red sandstone with fauna of Hardgrave sandstone.			Fant meta-andesite. Hardgrave sandstone.				
	Middle Lias or Charmouthian.	Talkeetna formation.	Maude formation; argillite, sandstone, and tuff.											Bagley andesite; flows and tuff. Modin formation; sandstone and shale underlain by volcanic conglomerate.	Trail formation.			Micaceous clay slate with *Arietites* in Puebla and Vera Cruz; plant beds in Vera Cruz, Puebla, and Oaxaca.	
	Lower Lias.	Calcareous sandstone, sandy, shale, and limestone of Cape Kekurnoi region.								Slate with some limestone containing *Arietites* (*Caloceras*) cf. *A. nodotianus* D'Orbigny.									

[a] McKenzie, J. D., Canada Geol. Survey Mem. 88, No. 1622, pp. 40–51, 1916.
[b] Leach, W. W., Canada Geol. Survey Summ. Rept. for 1911, pp. 93–94. McConnell, R. G., Canada Geol. Survey Summ. Rept. for 1912, pp. 58–59. O'Neill, J. J., Canada Geol. Survey Mem. 110, pp. 4–5, 1919.
[c] Dawson, G. M., Canada Geol. Survey Rept. Progress for 1876–77, pp. 58–66. Whiteaves, J. F., idem, pp. 150–159.
[d] Dawson, G. M., Canada Geol. Survey Ann. Rept., new ser. vol. 7, pp. 51B, 113B, 115B, 1896.
[e] Dowling, D. B., Canada Geol. Survey Pub. 949, pp. 8–9, 36–37, 1907.
[f] Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 118, 1920.
[g] Louderback, G. D., Geol. Soc. America Bull., vol. 15, p. 295, 1904. Smith, J. P., California Acad. Sci. Proc., 3d ser., vol. 1, p. 364, 1904.
[h] Smith, G. O., and Calkins, F. C., U. S. Geol. Survey Bull. 235, p. 27, 1904.
[i] Hyatt, Alpheus, Geol. Soc. America Bull., vol. 5, p. 401, 1894.
[j] Stanton, T. W., U. S. Geol. Survey Bull. 133, pp. 30–31, 1895. Diller, J. S., Am. Jour. Sci., 4th ser., vol. 23, pp. 401–421, 1907. Smith, J. P., Science, new ser., vol. 30, pp. 347–348, 1909. Knowlton, F. H., Am. Jour. Sci., 4th ser., vol. 30, pp. 33–64, 1910.
[k] Diller, J. S., U. S. Geol. Survey Geol. Atlas, Redding folio (No. 138), 1906.
[l] Diller, J. S., U. S. Geol. Survey Bull. 353, 1908.
[m] Smith, J. P., Geol. Soc. America Bull., vol. 5, pp. 243–248, 1894. Hyatt, Alpheus, idem, pp. 403–413. Turner, H. W., and Ransome, F. L., U. S. Geol. Survey, Geol. Atlas, Sonora folio (No. 41), 1897. Lindgren, Waldemar, U. S. Geol. Survey, Geol. Atlas, Colfax folio (No. 66), 1900. Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 118, 1920.
[n] Cragin, F. W., U. S. Geol. Survey Bull. 266, 1905.
[o] Various authors cited by Willis, Bailey, U. S. Geol. Survey Prof. Paper 71, 1912; De Lapparent, A., traité de géologie, 1893, and Stanton, T. W., Geol. Soc. America Bull., vol. 29, pp. 604–605, 1918.
[p] O'Connell, Marjorie, Geol. Soc. America Bull., vol. 31, p. 136, 1920; Am. Mus. Nat. Hist. Bull., vol. 42, pp. 643–692, 1920.

Talkeetna formation, of Middle (?) Liassic age; and the Kialagvik formation, of Upper Liassic (?) age. The writer believes that these formations possibly represent, in a general way, the subdivisions of the Liassic mentioned, but it should be frankly admitted that there is very little evidence on which definite correlation of these rocks can be based. The evidence on the age and correlation of the rocks of the several districts has been given on the preceding pages in some detail. The general character of the Lower Jurassic faunas and floras is also indicated in the following table.

Lower Jurassic floras and faunas

	1	2	3	4	5	6	7
Cladophlebis hirta? Möller		X					
Cladophlebis					X		
Dictyophyllum nilssoni (Brongniart) Göppert		X					
Sagenopteris	X	?					
Glossozamites? schrenkii?	X						
Otozamites pterophylloides Brongniart		X					
Otozamites bornholmiensis? Möller		X					
Pterophyllum rajmahalense Mörris		X					
Pterophyllum aequale (Brongniart) Nathorst		X					
Pterophyllum?	X						
Ctenophyllum angustifolium? Fontaine		X					
Nilssonia polymorpha Schenk		X					
Pagiophyllum falcatum Bartolin		X					
Stem	X						
Montlivaultia?			X				
Astrocoenia?			X				
Undetermined coral			X				
Pentacrinus cf. P. subangularis Miller						X	X
Pentacrinus			X				
Rhynchonella	X	X			X		
Terebratula	X						
Solemya	X						
Nucula?	X						
Leda	X						
Grammatodon					X		
Nemodon?		X					
Cucullaea increbescens White					X		
Cucullaea					X		
Pinna cf. P. expansa Hyatt			X				
Pinna					X		
Gervillia		?			X		
Perna??			X				
Inoceramus lucifer Eichwald?					X	X	
Inoceramus					X		
Pteria					X		
Eumicrotis?					X		
Ostrea		X	X		X		
Gryphaea	X	?	X				
Cardinia		?	X				
Myophoria?			X				
Trigonia (Costatae group)					X		
Trigonia (Glabrae group)	?	X			X		
Trigonia (Clavellatae group)					X		
Trigonia		X	X		X		
Pecten	X	X	X		X		
Pecten (Vola type)		X					
Janira				X			
Lima cf. L. gigantea Sowerby	X				X		
Lima		X			X		
Anomia?			X		X		
Modiola		X					
Pleuromya dalli (White)					X		
Pleuromya	?	X	X		X		
Arcomya crassissima Eichwald				X			

Lower Jurassic floras and faunas—Continued

	1	2	3	4	5	6	7
Anatina (Cercomya)			×				
Thracia?		×			×		
Cypricardia?					×		
Astarte?		×					
Tancredia?					×		
Protocardia		×			×		
Venerids?					×		
Pelecypods	×	×					
Pleurotomaria?	×		×				
Turbo					?		
Pseudomelania?			×				
Natica			?		×		
Cerithium					×		
Undertermined gastropods		×					
Aegoceras?	×	×					
Phylloceras	?				×		
Arietites?	×		×				
Amaltheus?	×						
Hammatoceras howelli (White)					×	×	
Hammatoceras cf. H. variabile (D'Orbigny)					×		
Hammatoceras? kialagvikense (White)					×		
Sonninia		×			?		
Harpoceras whiteavesi (White)					×	×	
Harpoceras						×	
Dactylioceras?					×		
Deroceras?		×					
Stephanoceras?	×				×		
Undetermined ammonites	×	×	×				
Belemnites					×		
Bone (fragments)	×						

1. Basal (unnamed) Jurassic formation of Alaska Peninsula.
2. Talkeetna formation of Matanuska Valley.
3. Tuffs of Kenai Peninsula.
4. "English Bay."
5. Kialagvik formation (Lower or Middle Jurassic).
6. Kingak shale (Lower or Middle Jurassic).
7. Crinoid bed of Firth River.

The basal Jurassic rocks of Alaska Peninsula are assigned to the base of the Alaskan Jurassic sequence and are correlated with the Lower Lias because they lie with apparent conformity on Upper Triassic rocks and contain ammonites that have been questionably identified as *Aegoceras*, *Arietites*, and *Amaltheus*, which are indicative of the Lower or Middle Lias. Collections made in 1924 by W. R. Smith on the shores of Cold and Alinchak bays indicate that the Kialagvik fauna may also be present in this area.

The Talkeetna horizon is assigned to the next higher position in the Alaskan Jurassic sequence and is tentatively correlated with the Middle Lias because there is no evidence that it immediately succeeds the Upper Triassic rocks, except in Kenai Peninsula, where it may lie unconformably upon them, and because it contains ammonites, such as *Aegoceras* and *Deroceras*, which are indicative of the Lower or Middle Lias. The fossil plants, according to Knowlton, suggest a correlation with the Rhaetic or Lias flora of the Island of Bornholm, off the coast of Sweden, but are seemingly not indicative of any special position within the Lias. The equivalent of the Talkeetna formation may possibly be found in the argillite, sandstone, and tuff of the Maude formation [72] of Graham Island, B. C.,

[72] McKenzie, J. D., Canada Geol. Survey Mem. 88, No. 1622, pp. 40–51, 1916.

and in the upper but not the very highest part of the Nicola series[73] of the Kamlops district, B. C. The Bagley andesite[74] of California may also belong at the same horizon.

The Kialagvik formation, which has been referred to the Middle Jurassic by Hyatt and by Stanton and to the Upper Lias by several European paleontologists, is here referred tentatively to the Upper Lias, chiefly because its characteristic ammonites, *Hammatoceras*, *Harpoceras*, and *Dactylioceras*, have been regarded as indicative of the Upper Lias (Toarcian), and because the writer believes that there is no connection between its fauna and that of the Tuxedni sandstone except in the presence of *Inoceramus lucifer* Eichwald. Its American equivalents, outside of Alaska, may perhaps be found in the upper part of the Nicola series[75] of British Columbia and in the Hardgrave sandstone or the Mormon sandstone of California.[76]

MIDDLE JURASSIC

The Middle Jurassic rocks of Alaska include only the Tuxedni sandstone and its equivalents, unless the rocks of the Kialagvik horizon are Middle Jurassic. The Tuxedni sandstone contains a large marine fauna, which has not yet been exhaustively studied and whose precise position has therefore not yet been determined. The general character of the fauna and the presence of ammonites related to *Stephanoceras humphriesianum* (Sowerby) and *Parkinsonia parkinsoni* Sowerby indicate a correlation with the Bajocian or Inferior oolite of Europe. The great thickness of the Tuxedni sandstone and its position conformably beneath the Chinitna shale, which is of Callovian age, suggest that it may also represent part or all of the Bathonian or Great oolite. In this connection it should be noted that *Parkinsonia parkinsoni* occurs in some of the Bathonian beds of Europe. The presence in the Tuxedni fauna of *Harpoceras* and of *Lima* cf. *L. gigantea* Sowerby suggest that it may also include part of the Upper Lias. The writer believes that the Tuxedni horizon certainly represents the Bajocian, that it probably represents part or all of the Bathonian, and that it possibly represents part of the Upper Lias of Europe.

The equivalents of the Tuxedni in British Columbia include the basaltic agglomerate, lava, and tuff and tuffaceous sandstone of the Yakoun formation[77] of Graham Island; the lower part of the andesitic porphry and tuff and fossiliferous sandstone and shale

[73] Dawson, G. M., Canada Geol. Survey Ann. Rept., new ser., vol. 7, pp. 51B, 113B, 115B, 1896.
[74] Diller, J. S., U. S. Geol. Survey Geol. Atlas, Redding folio (No. 138), 1906.
[75] Dawson, G. M., op. cit., pp. 51B, 113B, 115B.
[76] Diller, J. S., U. S. Geol. Survey Bull. 353, 1908.
[77] McKenzie, J. D., Canada Geol. Survey Mem. 88, No. 1622, pp. 40–51, 1916.

of the Hazelton group[78] of Skeena River; at least part of the porphyry, tuff, and sedimentary rocks of the Porphyrite series[79] of Iltasyoucou (Dean) River; and possibly the uppermost part of the Nicola series[80] of the Kamloops district. It is probably represented in California by the Mormon sandstone and Thompson limestone of the Taylorsville region[81] and by the upper part of the Potem formation of the Redding quadrangle.[82]

The fauna and flora of the Tuxedni sandstone as found in several Alaskan districts are listed in the following table:

Middle Jurassic (Tuxedni) fauna and flora

	1	2	3	4	5
Cladophlebis	×				
Marattiopsis or Danaeopsis	×				
Sagenopteris göppertiana Zigno	×		×		
Sagenopteris	×				
Macrotaeniopteris californica Fontaine	×				
Nilsonia orientalis Heer	×				
Nilsonia	×				
Pterophyllum rajmahalense Morris	×				
Pterophyllum or Zamites	×				
Fieldenia nordenskiöldi Nathorst?	×				
Fieldenia?	×				
Pagiophyllum?	×				
Phoenicopsis?	×				
Stems	×				
Fossil wood	×				
Serpula	×				
Undetermined corals			×		
Echinoid spine				×	
Rhynchonella	×		×		
Terebratula	×		×		
Trails or burrows			×		
Leda?					×
Grammatodon	×		×		
Nemodon?			×		
Cucullaea	×		×		
Arca	×				
Pinna	×		×		
Gervillia	×				
Inoceramus ambiguus Eichwald	×		×		?
Inoceramus eximius Eichwald	×	?		×	
Inoceramus cf. I. lucifer Eichwald	×	?	×	×	
Inoceramus porrectus Eichwald?	×				
Inoceramus	×		×	×	×
Avicula	×		×		
Pteria	×				
Eumicrotis cf. E. curta Hall	×	?			
Eumicrotis	×		?		
Ostrea	×	?			
Exogyra	×				
Trigonia devexa Eichwald	×				
Trigonia doroschini Eichwald	×				
Trigonia cf. T. dawsoni Whiteaves	×		×		

[78] Leach, W. W., Canada Geol. Survey Summ. Rept. for 1911, pp. 93–94. McConnell, R. G., Canada Geol. Survey Summ. Rept. for 1912, pp. 58–59. O'Neill, J. J., Canada Geol. Survey Mem. 110, pp. 4–5, 1920.

[79] Dawson, G. M., Canada Geol. Survey Rept. Progress for 1876–77, pp. 58–66, Whiteaves, J. F., idem, pp. 150–159.

[80] Dawson, G. M., Canada Geol. Survey Ann. Rept., new ser., vol. 7, pp. 51B, 113B, 115B, 1896.

[81] Diller, J. S., U. S. Geol. Survey Bull. 353, 1908.

[82] Diller, J. S., U. S. Geol. Survey Geol. Atlas, Redding folio (No. 138), 1906.

Middle Jurassic (Tuxedni) fauna and flora—Continued

	1	2	3	4	5
Trigonia (clavellatae)	×				
Trigonia (undulatae)	×				
Trigonia	×		×		
Pecten	×		×		
Camptonectes	×		?		
Lima cf. L. gigantea Sowerby	×		×		
Lima	×		?		
Anomia	×				
Modiola	×				
Pleuromya carlottensis Whiteaves?			×		
Pleuromya	×	?	×		
Pholadomya	×				
Goniomya	×				
Anatina?	×				
Thracia cf. T. semiplanata Whiteaves			×		
Thracia	×		?		
Arctica	×				
Cyprina?	×		×		
Praeconia?	×				
Astarte	×		?		
Tancredia?	×				
Lucina	×				
Sphaeriola?	×				
Protocardia	×		×		
Isocardia	?		×		
Undetermined Veneridae	×				
Quenstedtia?	×				
Undetermined Solenidae?	×				
Dentalium?	×				
Pleurotomaria	×		×		
Turbo?	×				
Amberleya	×		×		
Natica	×		×		
Turritella?	×				
Nerinea			×		
Cerithium	×				
Alaria?	×				
Aporrhais?	×				
Actaeon?	×				
Phylloceras	×		×		
Haploceras?	×				
Lytoceras	×				
Oppelia?	×		×		
Sonninia?	×	?	×		
Harpoceras	×				
Stephanoceras cf. S. humphriesianum (Sowerby)	×		×		
Stephanoceras richardsoni Whiteaves	×				
Stephanoceras	×	?	×		?
Stephanoceras? cf. S. loganianus (Whiteaves)	×				
Stephanoceras? cf. S. carlottensis (Whiteaves)	×				
Sphaeroceras cf. S. cepoides (Whiteaves)	×				
Sphaeroceras cf. S. oblatum (Whiteaves)	×		×		
Sphaeroceras	×		×		
Macrocephalites	×				
Perisphinctes	×				?
Parkinsonia? cf. P. parkinsoni Sowerby	×				
Belemnites (slender form)	×				
Belemnites (hastate form)	×				
Belemnites	×	?	×		

1. Cook Inlet.
2. Alaska Peninsula (Tuxedni sandstone).
3. Matanuska Valley (Tuxedni sandstone).
4. Alaska Range (Tordrillo formation).
5. Chitina Valley (tuffaceous slate).

UPPER JURASSIC

The Upper Jurassic rocks of Alaska embrace three faunal divisions—the *Cadoceras* zone at the base (represented in the Chinitna and Shelikof formations), the *Cardioceras* zone next above (represented in the lower part of the Naknek formation), and the *Aucella* zone at the top (represented in the upper part of the Naknek formation.)

The Chinitna fauna is characterized by the genus *Cadoceras*, which is indicative of a position in the Callovian at the base of the Upper Jurassic of Europe. This fauna has not been found in North America outside of Alaska, but the possible equivalent of the Chinitna horizon may be found in the Bicknell sandstone[83] of the Taylorsville region of California and possibly in the lower part of the Ellis formation[84] of Montana.

The fauna and flora of the Chinitna horizon as found in the several Alaskan districts are listed in the following table:

Fauna and flora of the Upper Jurassic Cadoceras zone of Alaska

	1	2	3	4	5
Coniopteris burejensis (Zalessky) Seward					×
Cladophlebis denticulata (Brongniart) Seward	×				
Dictyophyllum cf. D. obtusilobum	×				
Hausmannia?	×				
Taeniopteris					×
Ctenis grandifolia Fontaine	×				
Nilsonia cf. N. orientalis Heer	×				
Phoenicopsis speciosa Heer	×				
Plant fragments	×				
Fossil wood	×				
Cidaris?					×
Serpula	?				×
Bryozoa?	×				
Rhynchonella	×	×		?	
Terebratula				×	?
Solemya					×
Nucula				×	×
Leda	?			×	×
Grammatodon	×			×	×
Cucullaea		×			
Pinna				×	
Inoceramus cf. I. eximius Eichwald			?		
Inoceramus	×			×	
Avicula	×	×		?	×
Pteria	×			×	×
Eumicrotis?				×	
Ostrea					×
Gryphaea		×			
Trigonia	×	×			
Pecten	×	×		×	
Lima	×				
Modiola?	×				
Pleuromya	×	×		×	×
Pholadomya	×				
Goniomya	×			×	?
Thracia	×			×	×
Cyprina		×			
Astarte	×	×		×	×
Lucina?	×				
Corbis? (or Astarte)				×	
Cardium?					×
Protocardia					×
Isocardia		×			
Venerid?	×				×
Tellina?	×				
Pelecypods	×				×
Dentalium	×			×	×
Turbo	×			?	?
Amberleya	×			×	×
Rissonina?				×	
Cerithium	×				
Tornatellaea?				×	

[83] Diller, J. S., U. S. Geol. Survey Bull. 353, 1908.
[84] Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 118, 1920.

Fauna and flora of the Upper Jurassic Cadoceras zone of Alaska—Continued

	1	2	3	4	5
Gastropods	×				×
Phylloceras subobtusiforme Pompeckj	?			?	
Phylloceras	×			×	×
Oxynotoceras?	×				
Harpoceras?	×				
Stephanoceras cf. Ammonites asterianus (Eichwald)	×				
Kepplerites? cf. K. loganianus (Whiteaves)	×				
Sphaeroceras	×				
Macrocephalites	×				
Cadoceras catostoma Pompeckj	?			×	
Cadoceras doroschini (Eichwald)	×	×		×	
Cadoceras grewingki Pompeckj	?			×	
Cadoceras petelini Pompeckj				?	
Cadoceras schmidti Pompeckj	×			×	
Cadoceras stenoloboide Pompeckj	×			×	
Cadoceras cf. C. tchefkini (D'Orbigny)				?	
Cadoceras wosnessenski Grewingk	×			×	
Cadoceras	×	×		×	
Cosmoceras?	×				
Ammonite				×	
Belemnites	×	×		×	
Crustacean	×				

1. Chinitna shale of Cook Inlet.
2. Chinitna formation of the Matanuska Valley.
3. Shelikof formation, Alaska Peninsula, lower member.
4. Shelikof formation, Alaska Peninsula, middle member.
5. Shelikof formation, Alaska Peninsula, upper member.

The *Cardioceras* zone of Alaska contains a characteristic marine fauna, listed below, in which the most significant members are several species of *Cardioceras*. This genus is indicative of a correlation with the Argovian or Lower Oxfordian and perhaps with part of the Sequanian or Upper Oxfordian of the European section.

The North American equivalents of the Alaskan *Cardioceras* zone include the Fernie shale of Alberta,[85] the upper part of the Ellis formation of Montana,[86] and the Sundance formation of Wyoming, Colorado, and Utah.[86]

Fauna and flora of the Upper Jurassic Cardioceras zone of Alaska

	1	2	3
Plant fragments	×		
Grammatodon	×		
Arca	×		
Pinna	×		
Inoceramus	×		
Avicula	×		×
Pteria	×		
Eumicrotis?	×		
Pecten	×		
Pleuromya	×		
Goniomya	×		
Thracia	×		
Arctica?	×		
Cyprina?	×		
Astarte	×		×
Isocardia			×
Corbula?	×		
Pelecypods	×		

	1	2	3
Gastropods	×		
Phylloceras	×		×
Lytoceras	×		
Cardioceras alaskense Reeside	×		
Cardioceras cf. C. canadense (Whiteaves)		?	
Cardioceras distans (Whitfield)	×		
Cardioceras distans var. depressum Reeside	×		
Cardioceras hyatti Reeside	×		
Cardioceras lillooetense Reeside	×		
Cardioceras martini Reeside	×		×
Cardioceras spiniferum Reeside	×		
Cardioceras n. sp.	×		
Belemnites	×		×
Crustacean	×		

1. Lower part of Naknek formation of Cook Inlet.
2. Naknek formation of Alaska Peninsula.
3. Naknek formation of Matanuska Valley.

[85] Dowling, D. B., Canada Geol. Survey Pub. 949, pp. 8–9, 36–37, 1907.
[86] Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 118, 1920.

The upper part of the Naknek formation and equivalent rocks in Alaska is characterized especially by several species of *Aucella* related to *Aucella bronni* Rouillier, *A. erringtoni* (Gabb), *A. fischeriana* (D'Orbigny), and *A. pallasi* Keyserling. The position of these rocks and the presence in them of the Jurassic type of *Aucella* indicate that they are to be correlated with the Kimmeridgian and Portlandian of Europe. They represent the boreal type of the Upper Jurassic. The North American equivalents of these rocks include the upper part of the Hazelton group of Skeena River, in British Columbia;[87] the sandstone, slate, and conglomerate containing *Aucella erringtoni* in the Cascade Mountains of Washington;[88] the Galice and Dothan formations and possibly the lower part of the Myrtle formation and of the Knoxville formation of western Oregon and northern California;[89] the Mariposa slate of the Sierra Nevada, Calif.;[90] and the *Aucella*-bearing beds near Mazapil, Mexico.[91] The probable equivalents of the *Aucella* zone as represented by strata that carry faunas of different type may be found in the Hinchman sandstone and possibly in the Foreman formation of the Taylorsville region, Calif.,[92] in various Upper Jurassic rocks of Mexico,[91] probably in some of the Upper Jurassic limestones of Cuba,[93] and possibly in the Malone formation of Texas.[94]

The fauna and flora of the *Aucella* zone of Alaska are represented in the following table:

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87 Leach, W. W., Canada Geol. Survey Summ. Rept. for 1911, pp. 93–94. McConnell, R. G., Canada Geol. Survey Summ. Rept. for 1912, pp. 58–59. O'Neill, J. J., Canada Geol. Survey Mem. 110, pp. 4–5, 1920.

88 Smith, G. O., and Calkins, F. C., U. S. Geol. Survey Bull. 235, p. 27, 1904.

89 Stanton, T. W., U. S. Geol. Survey Bull. 133, pp. 30–31, 1895. Diller, J. S., Am. Jour. Sci., 4th ser., vol. 23, pp. 401–421, 1907. Smith, J. P., Am. Jour. Sci., 4th ser., vol. 30, 1910, pp. 33–64, 1910.

90 Smith, J. P., Geol. Soc. America Bull., vol. 5, pp. 243–248, 1894. Hyatt, Alpheus, idem, pp. 403–413. Turner, H. W., and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Sonora folio (No. 41), 1897. Lindgren, Waldemar, U. S. Geol. Survey Geol. Atlas, Colfax folio (No. 66), 1900. Reeside, J. B., jr., U. S. Geol. Survey Prof. Paper 118, 1920.

91 Various authors cited by Willis, Bailey, U. S. Geol. Survey Prof. Paper 71, 1912; De Lapparent, A., Traité de géologie, 1893; and Stanton, T. W., Geol. Soc. America Bull., vol. 29, pp. 604–605, 1918.

92 Diller, J. S., U. S. Geol. Survey Bull. 353, 1908.

93 O'Connell, Marjorie, Geol. Soc. America Bull., vol. 31, p. 136, 1920; Am. Mus. Nat. Hist. Bull., vol. 42, pp. 643–692, 1920.

94 Cragin, F. W., U. S. Geol. Survey Bull. 266, 1905.

Fauna and flora of the Upper Jurassic Aucella zone of Alaska

	1	2	3	4	5	6
Cladophlebis cf. C. haiburnensis (Lindley and Hutton)	×					
Polypodium oregonense Fontaine	×					
Zamites megaphyllus (Philips) Seward	×					
Cidaris?	×					
Serpula	×		?			
Rhynchonella	×					
Terebratula	×			?		
Nucula	×					
Leda	?	×				
Grammatodon	×					
Cucullaea?		×				
Arca	×					
Inoceramus	×	×	×	?		
Avicula	×	×				
Pteria	×					
Eumicrotis	×	?	×			
Aucella cf. A. bronni Rouillier	×		×	×		
Aucella cf. A. erringtoni (Gabb)	×	×				
Aucella cf. A. fischeriana (D'Orbigny)					×	
Aucella cf. A. pallasi Keyserling	×		×			
Aucella	×	×	×	×	×	×
Ostrea	×					
Trigonia cf. T. doroschini Eichwald		×				
Pecten	×	×	×	?		?
Lima	×					
Anomia?	×					
Modiola (small form)		×				
Pleuromya	×	×				
Pholadomya	×					
Thracia?		×				
Cypricardia?	×					
Arctica	×					
Cyprina	×					
Praeconia?		×				
Astarte	×	×		?		
Tancredia	×	×	×	?		
Panopaea?	×	×				
Pelecypods				×		
Dentalium	×	×				
Patella	×					
Turbo	×	?	×			
Amberleya	×	?				
Natica	×					
Rissoina?	×					
Alaria?				?		
Gastropods (undetermined)	×					
Phylloceras	×	×				
Lytoceras	×	×				
Cardioceras cf. C. canadense Whiteaves	?					
Perisphinctes	×					
Ammonite	×			?		
Belemnites	×	×	×		×	
Crustacean	×					
Plesiosaur	×					
Bone fragment	×					

1. Naknek formation of Alaska Peninsula.
2. Upper part of Naknek formation of Cook Inlet.
3. Naknek formation of Matanuska Valley.
4. Slate, graywacke, and conglomerate of Nutzotin Mountains.
5. Graywacke of Chichagof Island.
6. Slate, limestone, and tuff of Gravina Island.

CHRONOLOGIC RECORD

There was a general emergence of the land at the end of Triassic time, when the sea probably retired beyond the present continental limits. The evidence for this emergence is found in the fact that the latest Triassic (Rhaetic) is not represented in Alaska and that the earliest Jurassic, if present, occurs only in very narrow areas close to the present shore.

The beginning of the local record in Jurassic time in Alaska was marked by a moderate submergence accompanied or followed by intense volcanic activity along the present Pacific seaboard. The oldest known Jurassic sediments in Alaska are probably the shale and calcareous sandstone which overlie the Upper Triassic beds at Cold and Alinchak Bays, on the Alaska Peninsula.

The lava, agglomerate, breccia, and tuff, with interbedded marine fossiliferous strata, of the Talkeetna formation of the Talkeetna Mountains and the Matanuska Valley and their probable equivalent at Seldovia mark a broader and probably somewhat later transgression of the Lower Jurassic sea. The volcanic activity of this period has probably left a record also in the porphyry and tuff of the west coast of Cook Inlet, in the Skwentna group of the Yentna and Skwentna valleys, possibly in the conglomeratic rocks of the upper Susitna Valley and of the lower Chitina Valley, and probably in some of the volcanic rocks of southeastern Alaska. The volcanic activity and the marine transgression of this period were apparently limited to the region south of the Alaska Range and were best developed in the site of the present Cook Inlet basin.

A still later period of deposition, which was either late Lower Jurassic or early Middle Jurassic, is indicated by the sandstone and shale of the Kialagvik formation of the Alaska Peninsula, and by the Kingak shale of the Arctic coast, which carries a closely related fauna. This period of marine transgression was apparently the only one that brought any part of Alaska north of the Alaska Range beneath the sea in Jurassic time.

It is highly probable that the intrusion of the granitic masses of the Pacific coast began during the period of Lower Jurassic volcanic activity. It did not culminate, however, till Middle Jurassic time, and it continued, probably on a rapidly declining scale, till an unknown date in the Cretaceous.

The earliest known deposits of Middle Jurassic age in Alaska are those of the Tuxedni sandstone, which is typically developed on the west coast of Cook Inlet. The fauna of the Tuxedni sandstone has been recognized on the Alaska Peninsula, in the Matanuska Valley, in the Tordrillo formation of the Yentna and Skwentna Valleys, and in the lower part of the Chitina Valley. The Tuxedni sea probably covered all of south-central Alaska south of the Alaska Range. Its deposits were dominantly sandy, although they include, in the Chitina Valley, beds of tuffaceous slate. These slate beds may indicate either local volcanism or the local reworking of older volcanic detritus. The second alternative is believed to be the more probable. Volcanic deposits of Tuxedni age are known in British Columbia and may be present in southeastern Alaska.

7-8 - shower

8-10 →
Speech

Alaska - Canadian
arctic, Greenland,
Spitzbergen -

10-11 - Lecture

11-12 - Class

12-3 - ← Speech →
Notes
(Intro)

3-4 - Class

4-7 - off - 7-11
Type

JONES TOWER

NAME Mikan

ROOM # 628 TIME 1:30

MESSAGE Please call

Youngstown State U.

Dept of Geology

before 12 noon tomorrow

DATE 5/18 STAFF Ali

9:00 AM /

The Tuxedni sandstone and its synchronous deposits were laid down in an encroaching sea. It rests unconformably upon the nonmarine and supposed Lower Jurassic porphyry and tuff of the west coast of Cook Inlet. Its relations to the marine Lower Jurassic beds are not definitely known, although there are reasons for suspecting that in the Matanuska Valley, at least, the contact is unconformable.

The deposition of the Tuxedni sandstone was followed without any known interruption, by that of the oldest of the Upper Jurassic beds. These include the Chinitna shale of Cook Inlet and beds carrying the same fauna on the Alaska Peninsula and in the Matanuska Valley. These beds contain a fauna of Callovian age characterized by the boreal ammonite *Cadoceras*. Their known distribution in Alaska is somewhat more restricted than that of the underlying Tuxedni beds, and hence it seems probable that the sea receded somewhat at the end of Tuxedni time, or else that erosion sometime during the Upper Jurassic removed all the marginal deposits of the Chinitna sea. Deposition was probably continuous from Tuxedni to Chinitna time, no evidence of an intervening unconformity having been found. The beginning of Chinitna time was marked by the change from the deposition of sandstone to that of shale and by the invasion of a boreal fauna.

The deposition of the beds of the *Cardioceras* zone was restricted to nearly the same limits as those of the *Cadoceras* zone (Chinitna horizon), the deposits of the *Cardioceras* zone being found on Cook Inlet, in the Matanuska Valley, and on the Alaska Peninsula. The transition from Chinitna time to the date of the *Cardioceras*-bearing beds was apparently marked by continuous sedimentation in a gradually shoaling sea. The fine shale of the Chinitna was succeeded by sandy shale, sandstone, and conglomerate of the *Cardioceras* zone within an apparently gradually contracting area, and the change was accompanied by the normal faunal succession.

The local deposition of very coarse conglomerate at about the date of the *Cardioceras*-bearing beds is further evidence of a shoaling of the Upper Jurassic sea, which probably was caused and certainly was accompanied by vigorous mountain growth. The coarse granitic detritus in the conglomerate of that date indicates that the granitic batholiths of the Pacific coastal region had probably then for the first time been unroofed over large areas. The immense size of many of the granite bowlders, some of which are too large to have been moved by ordinary rivers or by any other known agency except ice, indicates that the neighboring mountains, probably like the higher mountains of all geologic time, contained glaciers. There is,

however, no indication in the Jurassic of Alaska of a "glacial period" as the term is ordinarily used.

The Jurassic expansion of the sea reached its culmination in late Upper Jurassic time, when marine sediments were laid down in great thickness throughout the region south of the Alaska Range. The late Upper Jurassic was a period of intense crustal movements and of vigorous erosion, when a large quantity of fresh and only partly sorted detritus was delivered to the sea. The character and thickness of the deposits indicate that subsidence of the sea floor kept pace approximately with marine deposition, or that the deposition of the marine sediments in general kept pace with the subsidence of the sea floor, while any excess of detritus that came to rest on flood plains, deltas, and coastal plains was soon thereafter swept into the ocean. The area of the late Upper Jurassic marine sedimentation probably included all of south-central Alaska and was sharply bounded on the north by the present line of the Alaska Range.

Volcanic activities were manifest in the Cook Inlet and southwestern Alaska regions during part of the Upper Jurassic time. They were probably the surface expression of the later and presumably the smaller of the Coast Range batholiths.

The late Upper Jurassic sea probably was directly connected with the cold-water Upper Jurassic sea of northern Europe and Asia.

The character of the events that terminated Jurassic time in Alaska is not well known. It seems probably that at the end of the Jurassic the Alaskan lands were worn down and the Alaskan seas were largely filled with sediments. The latest Jurassic deposits, corresponding to the Purbeckian of Europe, and the earliest Cretaceous deposits have not been recognized in Alaska. The absence of these deposits indicates that the transition from Jurassic to Cretaceous time was marked in Alaska by a break in the sedimentary record.

CRETACEOUS SYSTEM

OCCURRENCE AND GENERAL CHARACTER

Cretaceous rocks are widely distributed through all the major geographic provinces of Alaska (see fig. 7) and are the present surface rocks in several large areas, notably in the lower Yukon region and southwestern Alaska. A widespread marine transgression in early Cretaceous time carried the sea over most if not all of the area which is now Alaska. There doubtless were several recessions of the sea during the Cretaceous period for the equivalents of some of the characteristic major divisions of the Cretaceous have not been recognized in Alaska, but the sea must have readvanced

again from time to time, for horizons well distributed throughout the Cretaceous are widely represented in the Territory. In general it is believed that Lower Cretaceous deposits were laid down in all the larger geographic provinces, but probably not over the entire

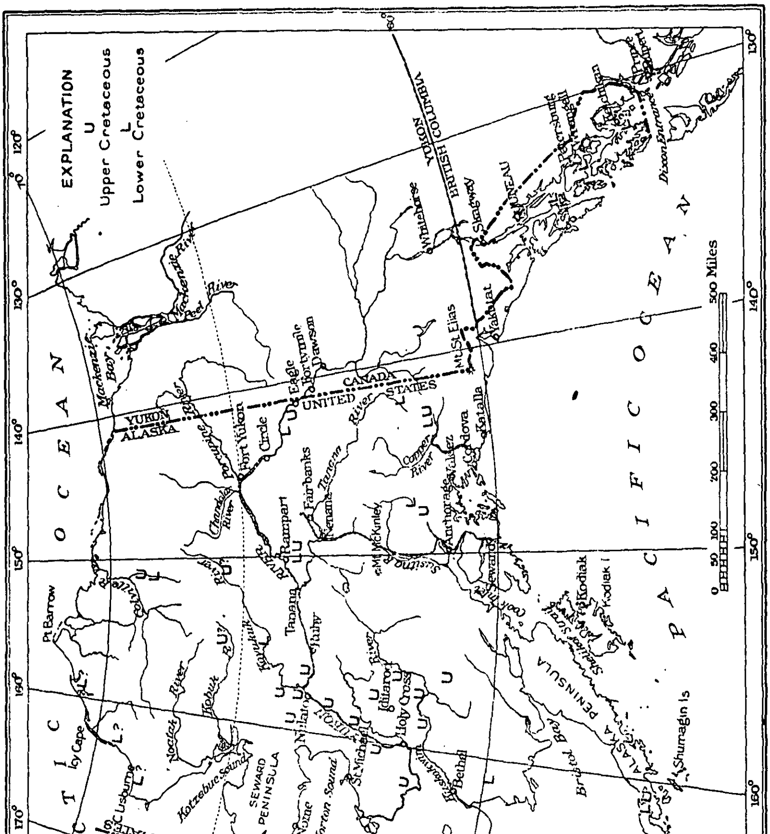

FIGURE 7.—Map of Alaska showing principal localities.

area of the Territory. The extent of the Lower Cretaceous seas, so far as known, was not limited along the lines of any of the existing geographic features. Upper Cretaceous deposits are also widely distributed and crop out at present over large areas, but there are several districts in which Upper Cretaceous rocks are not

known and, it is believed, were never deposited. The writer believes that the Upper Cretaceous marine transgressions were of less extent than those of the Lower Cretaceous sea and were excluded from most of the areas of the present mountain axes as well as from the upper parts of the present major valleys. In other words, the major geographic features seem to have been well outlined in Upper Cretaceous time, and the highest Cretaceous beds were restricted to coastal belts and to the present major valleys and included river deposits and possible lake and land deposits laid down in estuaries, valleys, and plains that were the direct predecessors of the existing lowlands.

The rocks that have been referred to the Lower Cretaceous include the Staniukovich shale and the Herendeen limestone of the Alaska Peninsula;[96] conglomerate tuff and arkose and the overlying Nelchina limestone of the Upper Matanuska Valley;[97] the shale, sandstone, and conglomerate of the Kennicott formation of the Chitina Valley;[98] some of the *Aucella*-bearing shale and graywacke of Chisana and White rivers;[99] some of the *Aucella*-bearing slate and associated rocks of southeastern Alaska;[1] the *Aucella*-bearing shale and sandstone of the upper Yukon[2] and Rampart-Tanana district;[3] the limestone, chert, and arkose of the "Oklune series" of the region north of Bristol Bay;[4] the limestone, shale, and sandstone of the Koyukuk group of the Koyukuk Valley;[5] and the sandstone and conglomerate of the Anaktuvuk group of northern Alaska.[6]

The rocks that have been referred to the Upper Cretaceous include the marine and terrestrial (coal-bearing) shale, sandstone, and conglomerate of the Chignik formation of the Alaska Peninsula,[7] which

[96] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 25, 38–41, pl. 8, 1911.

[97] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, p. 10, pl. 2, 1907.

[98] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 31–43, 1911. Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 27–45, 1918.

[99] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 29, 47–53, pl. 2, 1916.

[1] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pp. 143–144, 1906.

[2] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 305–307, 1908.

[3] Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pp. 20–21, 1913.

[4] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 133–134, 163–169, 181–182, 1900.

[5] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 53, 77, 97, pl. 3, 1904.

[6] Schrader, F. C., op. cit., pp. 53, 74–76, pl. 3.

[7] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 24, 41–48, 97–98, 100–103, 109–114, pls. 7, 8, 1911.

contain fossil plants; the marine shale and sandstone composing the Matanuska formation of the Matanuska Valley;[8] the marine shale, sandstone, arkose, and conglomerate of the Chitina Valley;[9] the nonmarine shale and sandstone exposed in the banks of the Yukon near Seventymile,[10] which were previously regarded as Tertiary and which contain fossil plants; a marine sandstone near Wolverine Mountain, in the Rampart district;[11] the marine and terrestrial (coal-bearing) shale, sandstone, and conglomerate of the lower Yukon[12] and Norton Bay-Nulato district,[13] which contain fossil plants; some of the shale and sandstone of the Innoko Valley;[14] the sandstone, limestone, and shale of the "Holiknuk series"[15] and some of the rocks of the "Kolmakof series"[16] of the Kuskokwim Valley; the shale, sandstone, and conglomerate of the lower Koyukuk Valley;[17] the shale, sandstone, and conglomerate of the Bergman group of the upper Koyukuk Valley;[18] and the sandstone, limestone, and shale of the Nanushuk formation of the Arctic slope.[19]

LOCAL SECTIONS

ALASKA PENINSULA

GENERAL FEATURES

The best-known and, so far as present information goes, the most complete section of Cretaceous rocks in Alaska is on the Alaska Peninsula, where both Lower and Upper Cretaceous strata are present and where the contacts with the underlying Jurassic and the overlying Tertiary beds have been observed. The Lower Cre-

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[8] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 15, 23, 34–39, pls. 3, 5, 1912.

[9] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 29–45, 1918.

[10] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, p. 28, 1903.

[11] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 33, 34, 47–48, 1913.

[12] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 15, 17, 19–20, 46–58, 65, 1903.

[13] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 54–60, 1911.

[14] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 23–24, pl. 3, 1914.

[15] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 125–128, 159–161, 182, 1900. Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 57–84, 1917.

[16] Spurr, J. E., op. cit., pp. 130–131, 161–163, 182–183.

[17] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk Rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept. pt. 2, p. 478, pl. 60, 1900.

[18] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 53, 77–79, 97, pl. 3, 1904.

[19] Idem, pp. 53, 79–81, pl. 3.

taceous beds carry marine faunas; the Upper Cretaceous beds have yielded not only characteristic marine invertebrate fossils but fossil plants. The general character and sequence of the Cretaceous rocks of the Alaska Peninsula is as follows:

General section of Cretaceous rocks on Alaska Peninsula

	Feet
Upper Cretaceous (overlain unconformably (?) by Eocene strata):	
Chignik formation:	
Upper member (conglomerate, sandstone, and shale with marine invertebrates and fossil plants)	300–500
Middle member (shale with many coal beds and some sandstone; contains fossil plants)	300+
Lower member (shale with marine fossils)	200±
Lower Cretaceous:	
Herendeen limestone (arenaceous limestone with *Aucella crassicollis*)	800
Staniukovich shale (thin-bedded shale, interbedded with thin strata of sandstone and with some conglomerate; (contains *Aucella piochii*); underlain conformably (?) by Upper Jurassic strata)	1000+

The Lower Cretaceous strata of the Alaska Peninsula overlie the Upper Jurassic rocks, described above (p. 210), with apparent conformity. They are known only in the vicinity of Herendeen Bay, near the west end of the peninsula. Farther east they are certainly absent at some places, as at Chignik, where the Upper Cretaceous rocks rest unconformably upon the Upper Jurassic rocks. At other places, as along the coast from Cold Bay to Cape Douglas, it is highly probable that they are absent, although positive proof is lacking. At still other places, as along the coast from Chignik Bay to Cold Bay and throughout the greater part of the interior of the peninsula, information is very scanty, and no definite statement can be made as to what formations are present, although there are reasons for believing (see p. 293) that there may be areas of Lower Cretaceous rocks. The writer believes that the Lower Cretaceous formations were deposited over broad areas in southwestern Alaska, and that the small size of the areas of their present occurrence is due to subsequent erosion or burial.

Upper Cretaceous beds are known at several localities at both the east and the west ends of the Alaska Peninsula. They overlie the Lower Cretaceous beds with a possible unconformity, and where the Lower Cretaceous rocks are absent they rest unconformably upon the Upper Jurassic rocks. They are overlain, unconformably in at least some places, by Tertiary beds.

LOWER CRETACEOUS

STANIUKOVICH SHALE

Historical review.—The Lower Cretaceous rocks of the Alaska Peninsula include two formations, the Staniukovich shale and the Herendeen limestone, both of which are now known only in the vicinity of Herendeen Bay.

The Staniukovich shale, which is the lower of these formations, was named and described by Atwood,[20] and the type locality is on Staniukovich Mountain, near the entrance to Port Moller. The account of this formation by Atwood consists of a very brief description of the general character and occurrence of the rocks, a short discussion of their stratigraphic relations, and lists of fossils as identified by T. W. Stanton.

Stratigraphic description.—The Staniukovich shale consists of thin-bedded shale, interbedded with thin strata of sandstone and with some conglomerate. Its thickness is at least 1,000 feet. It overlies the Upper Jurassic rocks of the Naknek formation with apparent conformity. The actual contacts with the Jurassic rocks are in most places along faults, but in one locality the Staniukovich formation was observed to overlie the Jurassic rocks with essentially parallel bedding, although the actual contact was obscured by loose material and vegetation. This formation is overlain conformably by the Herendeen limestone.

Age and correlation.—The fauna of the Staniukovich shale, as far as now known, probably includes only a single species of *Aucella*, which is related to *Aucella piochii* Gabb and which has been found at three localities, as described below. The material from locality 5572 includes also another species of *Aucella* which is related to *Aucella crassicollis* Keyserling. There is some doubt as to whether any of the specimens from this locality[21] came from the Staniukovich shale, and the writer believes it possible that this is float material in which two horizons are represented. T. W. Stanton[22] says regarding these collections:

> Judging from past experience in California and Oregon and from the recorded occurrence of similar forms in Russia and elsewhere, I would expect the various lots containing *Aucella* to have the following stratigraphic sequence:
>
> 1. Highest horizon, with forms related to *Aucella crassicollis*—5572 (part), 5575, 5585, 5589, 5586.
> 2. Somewhat lower horizon, still within the Lower Cretaceous, with form related to *A. piochii*—5571, 5572 (part), 5576.

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[20] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 25, 38–41, pl. 8, 1911.

[21] See discussion of "collection 13" by Atwood in U. S. Geol. Survey Bull. 467, p. 40, 1911.

[22] Unpublished letter.

3. Lower horizon referable to Upper Jurassic, with form related to *A. pallasi.*[23]

4. Lowest horizon but still Upper Jurassic, with form related to *A. bronni.*[23]

The mixture of forms in lot 5572 and the stratigraphic notes of Doctor Atwood on some of the others seem to indicate that the distinction between horizons 1 and 2 based on forms of *Aucella* will not hold in the Herendeen Bay district. It should be remembered also that Aucellas with difficulty distinguishable from *A. piochii* also occur in the Jurassic, so that the three lots associated under 2 may not all be from the same horizon.

The localities may be described as follows:

5571. East shore Herendeen Bay, about 1½ miles southeast of Crow Point. W. W. Atwood, 1908.

5572. West side of the basin of Coal Valley, east of Herendeen Bay, about 500 feet above sea level. "Coal series near head of Coal Valley. Shales, sandstones, and coal beds." W. W. Atwood, 1908.

5576. Between Shingle and Marble points, east shore of Herendeen Bay. "Sandstone and conglomerate horizon." W. W. Atwood, 1908.

HERENDEEN LIMESTONE

Historical review.—The Herendeen limestone, which is the upper of the two Lower Cretaceous formations of the Alaska Peninsula, was named and described by Atwood;[24] the type locality is on the east shore of Herendeen Bay. The rocks composing this formation and the fossils contained in them were previously known from the writings of several authors.

The first fossils known to have been obtained from the Herendeen limestone were collected at Port Moller by Dall in 1874. These fossils were described and figured by White,[25] and their occurrence was described very briefly by Dall.[26]

Another collection, obtained from an undescribed locality near Herendeen Bay by Ernest G. Locke, has been mentioned by Brooks.[27] This collection is of extreme interest because it includes both marine shells and a fossil plant, which, it has always been assumed, were obtained at the same locality. The marine shells collected by Locke, according to Stanton,[28] consist of *Aucella* cf. *A. crassicollis* Keyserling, which is the characteristic fossil of the Herendeen limestone, and are "almost certainly of Lower Cretaceous age." The plant has been described and figured by Fontaine[29] as *Pterophyllum*

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[23] These were obtained from the Naknek formation; see p. 203.—G. C. M.

[24] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 25, 39–41, pl. 8, 1911.

[25] White, C. A., On a small collection of Mesozoic fossils collected in Alaska by Mr. W. H. Dall, of the United States Coast Survey: U. S. Geol. Survey Bull. 4, pp. 10–15, pl. 6, 1884.

[26] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 804, 867, 1896.

[27] Brooks, A. H., The coal resources of Alaska: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, pp. 528–529, 1902.

[28] Stanton, T. W., idem, pp. 528–529.

[29] Fontaine, W. M., Plants from Herendeen Bay, Alaska (in Ward, L. F., Status of the Mesozoic floras of the United States, second paper): U. S. Geol. Survey Mon. 48, p. 152, pl. 38, figs. 19–20, 1905.

alaskense, a new species, which Fontaine considered related to the European Jurassic (Lias or Oolite) species *P. rajmahalense* Morris and which according to Knowlton [30] is "hardly to be separated from it."

The presence of Lower Cretaceous rocks containing *Aucella crassicollis* at Port Moller and Herendeen Bay was mentioned briefly by Stanton and Martin,[31] but no description of the rocks was given.

Other small collections of fossils from beds at this horizon were obtained in 1905 by Paige,[32] who gave the first discussion of the relations of the several formations occurring at Herendeen Bay. The account includes brief statements regarding the occurrence, lithologic character, and relations of the rocks, with statements concerning the identity and age of the fossils by T. W. Stanton.

The account of the Herendeen limestone by Atwood,[33] who, as stated above, was the first to describe these rocks under a formation name, includes a fairly detailed description of the occurrence, character, and stratigraphic relations of the Herendeen limestone, with lists of fossils as identified by T. W. Stanton.

Neither the Herendeen limestone nor any other rocks containing the *Aucella crassicollis* fauna are definitely known to occur elsewhere on the Alaska Peninsula than at Herendeen Bay and Port Moller. They are certainly absent at Chignik Bay (see p. 297), where Upper Cretaceous beds rest unconformably upon the Upper Jurassic. It is probable, however, that the formation is present at other localities farther east. Such occurrences are indicated by the reported presence of *Aucella crassicollis* among the fossils collected by Doroshin.[34] The fossils collected by Pinart [35] from "Nakkhalilik Bay, near Chigihinagak Volcano" (probably Chiginagak Bay), and from Aniakshak Bay, which were described by Fischer,[36] are probably Lower Cretaceous. Fischer afterward repeated the same description with figures.[37]

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[30] Knowlton, F. H., The Jurassic age of the "Jurassic flora of Oregon": Am. Jour. Sci., 4th ser., vol. 30, p. 50, 1910.

[31] Stanton, T. W., and Martin G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 407–408, 410, 1905.

[32] Paige, Sidney, The Herendeen Bay coal field: U. S. Geol. Survey Bull. 284, pp. 102–105, 1906.

[33] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 25, 38–41, pl. 8, 1911.

[34] Eichwald, Eduard von, Geognostisch-palaeontologische Bemerkungen über die Halbinsel Margischlak und die aleutischen Inseln, p. 187, St. Petersburg, 1871.

[35] Pinart, A. L., Voyage à la côte nord-ouest d'Amérique d'Ounalashka à Kadiak: Soc. Géog. (Paris) Bull., 6th ser., vol. 6, pp. 561–580, 1873.

[36] Fischer, P., Sur quelques fossiles de l'Alaska, rapportés par M. A. Pinart: Compt. Rend., vol. 75, pp. 1784–1786, 1872.

[37] Fischer, P., Sur quelques fossiles de l'Alaska, in Voyages à la cote nord-ouest de l'Amérique, pt. 1, pp. 33–36, pl. A, 1875.

Stratigraphic description.—The Herendeen limestone overlies the Staniukovich shale, described on pages 291–292, with apparent conformity and is overlain, probably unconformably, by the Upper Cretaceous rocks of the Chignik formation described on pages 295–308.

The Herendeen limestone was described by Atwood [38] as follows:

The upper portion of the Lower Cretaceous of this region is an arenaceous limestone of light-gray color, locally cross-bedded and fossiliferous. The formation is 800 feet thick, and owing to its superior resistance to the agents of weathering it has come to form conspicuous ridges in the coal field.

The Herendeen rock is a yellowish, sand-colored fine-grained limestone, with numerous minute plates of black mica on the sedimentation planes. Locally it contains abundant fragments of shells, and at places where the shell forms are lost the comminuted shell material may be recognized. The shells that have yielded most of such material were pectens. A microscopic examination of this rock shows that it is "mainly composed of dirty carbonate occurring in small short rectangular forms, but longer pieces are found, and these show curvature indicating a detrital organic origin. Throughout the section are scattered subangular fragments of quartz and plagioclase and sporadic flakes of biotite; as accessories there occur fragments of pyroxene, of rounded microlitic andesite, and grains of magnetite."

The Herendeen limestone, though folded and somewhat faulted, may be traced east from Coal Harbor for several miles, thence northwest until it outcrops on the shore of Herendeen Bay a little north of Coal Harbor. These outcrops are on the sides of a plunging syncline. Farther north the same arenaceous limestone outcrops again on the flanks of a neighboring anticline and extends east below recent volcanic tuffs and flows until it outcrops on the west shore of Port Moller.

Age and correlation.—The fossils of the Herendeen limestone, as listed in the following table, include a few species of marine mollusks and possibly a plant. The mollusks are indicative of Lower Cretaceous age, although the only characteristic fossil among them is the species of *Aucella* related to *Aucella crassicollis* Keyserling.

The *Aucella* related to *Aucella piochii* Gabb indicates a somewhat lower horizon (see pp. 291, 378, 474) than that of *Aucella crassicollis*, possibly being Upper Jurassic, and it may not belong in this list. Atwood [39] says that this collection "was secured from what was believed to be the Herendeen limestone, but the formation could not be absolutely identified because much of the region was covered by a heavy mantle of snow."

The fossil plant (*Pterophyllum alaskense* Fontaine) may also not belong in this list. It is considered by Knowlton (see pp. 292–293) practically identical with a characteristic Jurassic species. It was received, together with some specimens of *Aucella* cf. *A. crassicollis*, labeled as coming from the "coal measures" of Herendeen Bay, but there is no available information concerning the exact locality

[38] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, p. 39, 1911.

[39] Idem, p. 40.

or strata from which it was obtained. As the coal-bearing rocks of Herendeen Bay are Upper Cretaceous or Tertiary (see pp. 300–301), they could have yielded neither this plant nor the specimens of *Aucella*. It is consequently not safe to assume either that the label was intended to give other than a very general locality designation, or that the fossils all came from the same locality or formation. If the specimens of *Aucella* and the plant did come from the same beds, then the problem of the age of those beds is closely related to the Knoxville problem.

Fossils from Herendeen limestone of the Alaska Peninsula [a]

	W. H. D.	E. G. L.	S. P. 1	S. P. 2	5572	5575	5585	5586	5587	5589
?Pterophyllum alaskense Fontaine [b]		a								
Inoceramus									b	
Aucella cf. A. crassicollis Keyserling		b	b	b	b	b	b	b		b
Aucella concentrica Fischer var [c]	c									
?Aucella cf. A. piochii Gabb [d]					b					
Pecten (large smooth form)								b		
Pleuromya									b	
Cyprina? dallii White	c									
Desmoceras?									b	
Belemnites macrititis White	c									
Belemnites									b	

[a] a, Identified by Wm. M. Fontaine; b, identified by T. W. Stanton; c, identified by C. A. White.
[b] This plant is regarded by Knowlton as Jurassic and may not have been obtained from the Herendeen limestone. (See p. 294.)
[c] Probably the same as *Aucella* cf. *A. crassicollis*.
[d] This species possibly came from the Staniukovich shale. (See p. 294.)

W. H. D. Fossil Point, Port Moller. Limestone "at a bluff point at the head of the bay, about east by south by compass from the end of the long sand spit." W. H. Dall, 1874. Identified by C. A. White (U. S. Geol. Survey Bull. 4, pp. 10–15, 1884).

E. G. L. Herendeen Bay. Ernest G. Locke, 1901.

S. P. 1. Divide above Johnson tunnel stream. Sidney Paige, 1905.

S. P. 2. Beach one-fourth mile west of mouth of Coal Creek. Sidney Paige, 1905.

5572. West side of basin of Coal Valley about 500 feet above sea level. W. W. Atwood, 1908.

5575. Just south of Shingle Point, east side of Herendeen Bay. W. W. Atwood, 1908.

5585. High ridge south of Johnson tunnel in Mine Creek. W. W. Atwood, 1908.

5586. Sandstone near Hot Springs, Port Moller. W. W. Atwood, 1908.

5587. Southwest shore of Port Moller about half a mile north of Hot Springs. Shale above sandstone of 5586. W. W. Atwood, 1908.

5589. 1,100-foot hill about 3 miles northeast of Mine Harbor. W. W. Atwood, 1908.

UPPER CRETACEOUS

CHIGNIK FORMATION

Historical review.—The Upper Cretaceous rocks of the Alaska Peninsula were described by Atwood [40] as the Chignik formation, so named from its typical development on Chignik Bay.

[40] Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, pp. 24, 41–48, 97–98, 100–103, 109–114, pls. 7, 8, 1911.

The coal beds and inclosing strata on Chignik River, which belong in this formation, had previously been described briefly by Dall,[41] but his account deals chiefly with the coal and includes only a brief mention of the rocks, which at that time had not been named and were not known to be Cretaceous.

Dall gave a brief description also of the coal beds on Herendeen Bay,[42] which probably belong in this formation and which may possibly include also the beds that yielded some of the fossil plants (see p. 305) collected by Townsend at what is said to be nearly the same locality as the coal, but which have been described by Knowlton[43] as Tertiary.

The coal beds of the Chignik formation at Chignik Bay were described by Stone,[44] who made only brief references to the character of the rocks but pointed out that they included marine fossiliferous Upper Cretaceous beds.

The Upper Cretaceous rocks at Chignik Bay were described by Stanton and Martin,[45] who gave, in addition to the brief description of the rocks, a list of fossil plants identified by F. H. Knowlton, lists of marine mollusks identified by T. W. Stanton, and a discussion of the correlation of these rocks with the Upper Cretaceous of other regions. Brief mention was made also of the occurrence of marine Upper Cretaceous beds near the east end of the Alaska Peninsula.

The Chignik formation includes the Upper Cretaceous beds of Herendeen Bay that were described by Paige,[46] who collected the first fossils to be recognized as Upper Cretaceous from this locality. This account includes a very brief general description of the rocks, a discussion of their field relations, and lists and discussions of the plant and invertebrate fossils by F. H. Knowlton and T. W. Stanton.

The account of the Chignik formation by Atwood[47] includes detailed descriptions, with stratigraphic sections, of the Upper Cretaceous rocks in the Chignik Bay and Herendeen Bay districts, lists of the invertebrate and plant fossils with discussions of their age and correlation by T. W. Stanton and F. H. Knowlton, a general discussion of the stratigraphic relations, and descriptions of the occurrence and character of the coal.

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[41] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 801–803, 1896.

[42] Idem, pp. 805–807.

[43] Knowlton, F. H., A review of the fossil flora of Alaska, with descriptions of new species: U. S. Nat. Mus. Proc., vol. 17, No. 998, pp. 207–240, 1894.

[44] Stone, R. W., Coal resources of southwestern Alaska: U. S. Geol. Survey Bull. 259, pp. 163–166, 1905.

[45] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, pp. 408–410, 1905.

[46] Paige, Sidney, The Herendeen Bay coal field: U. S. Geol. Survey Bull. 284, pp. 102–106, 1906.

[47] Atwood, W. W., op. cit., pp. 24, 41–48, 97–98, 100–103, 109–114, pls. 7, 8.

A brief general description of the Chignik formation by Smith and Baker[48] was based partly on previous descriptions and partly on observations in part of the area by Smith in 1922.

Stratigraphic description.—The general character of the Chignik formation on Chignik Bay has been described by Atwood[49] as follows:

In the Chignik Bay region the Chignik formation consists of a series of sandstones, shales, conglomerates, and some valuable coal seams. The sandstones range from fine, even-grained sediments to grits. Many of the sandstones in this formation, as exposed in Nigger and Chignik heads, have a light green color when fresh but weather to black or to shades of brown in the cliffs. Ripple marks are not uncommon on the bedding planes, and in some of the strata there are large concretions. The conglomerates are conspicuous members in the series, for they are firmly cemented and form cliffs or even, in some places, overhanging ledges. These conglomerates in Chignik Head contain pebbles of granite, quartz, greenstones, and flint as large as 2 inches in diameter. Near the entrance to Chignik Lagoon there is a coarse conglomerate that for convenience in the field was spoken of as the cobble conglomerate. The stones in this conglomerate are commonly 3 or 4 inches in diameter, but some of the boulders found in it were 2 feet in diameter. This conglomerate is poorly bedded and in some places has a volcanic matrix. The stones include granites, basalts, quartz, and shale. There are lenses of sandstone and shale in the midst of the conglomeratic layer.

According to Atwood's geologic map of Chignik Bay and vicinity[50] the Chignik formation is composed of three unnamed members, the middle one of which contains coal beds. No complete section of the entire formation has been measured, nor have the character and relations of the members been described in detail. The following section, which was measured by Atwood[51] on the south shore of Chignik Bay and Chignik Lagoon from a point near Nigger Head to a point about 200 yards southwest of the native village, apparently represents the upper member of the formation:

Section of part of Chignik formation near Nigger Head, Chignik Bay

	Feet
1. Black shale (yielded collection 5797, invertebrates)	100
2. Cobble conglomerate	150
3. Shale with interbedded conglomerate	60
4. Sandstone and shale at Nigger Head (the shale yielded collection 5295, plants)	200
	510

The Chignik formation of the type area overlies the Upper Jurassic rocks of the Naknek formation unconformably, the Lower Cre-

[48] Smith, W. R., and Baker, A. A., The Cold Bay-Chignik district: U. S. Geol. Survey Bull. 755, pp. 169, 184–185, 1925.
[49] Atwood, W. W., op. cit., p. 41.
[50] Idem, pl. 7.
[51] Idem, p. 42.

taceous rocks being absent. It is overlain by Tertiary rocks, and the contact has been described as conformable,[52] but the writer believes that there is strong evidence of a marked unconformity.

The Chignik formation in the vicinity of Herendeen Bay was described by Atwood [53] as having the following general section:

Section of Chignik formation in Mine Creek

	Feet
Conglomerate	300+
Coal measures	300+
Shale	200±

The section given below, which was also measured by Atwood [54] at nearly the same place, shows the character of the coal-bearing beds in detail. It is evident from the thickness as given in these two sections that all of the detailed section below the uppermost conglomerate belongs in the coal-bearing member of the formation, the "coal measures" of the general section.

Section of coal-bearing rocks of Chignik formation on the south slope of Mine Creek valley, Herendeen Bay

	Ft.	in.
Conglomerate	300	
Sandstone, coarse, cross-bedded, with huge sandstone concretions weathering brown from abundance of limonite	50	
Sandy shale	20	
Coal seam, medium grade	3	
Sandstone, firm, cross-bedded, with fossil leaves	3	
Shale	5	
Coal		10
Shale	2	6
Shaly coal		6
Shale, with sandstone concretions	3	
Coal	1	
Shales	4	
Coal	1	2
Shaly sandstone, with sandstone concretions	4	
Coal		10
Shales	4	
Coaly shales	1	6
Shales	3	
Carbonaceous shales	1	
Shales	2	
Coal	1	
Shales	2	
Coaly shales, with shale partings	2	3
Coal, with bony partings and shaly bed	7	
Shales	1	8

52 Atwood, W. W., op. cit., p. 58.
53 Idem, p. 42.
54 Idem, pp. 100–101.

	Ft.	in.
Shaly coal	1	2
Shale	2	6
Coal	1	1
Shales	3	
Coal	2	
Shales	3	6
Coal	1	2
Shales		6
Coal	1	5
Shales, with sandstone concretions	4	
Coal	1	8
Shales and sandstone interbedded	15	
Coal		8
Shales	5	
Shaly sandstone	2	
Shales	50	
Coal	1	2
Shales	6	
Coaly shale		4
Shales	7	
Coal	1	
Shales	3	
Coal	1	
Shales, with sandstone concretions	40	
Coarse cross-bedded sandstone and conglomerates	15	
Shales and sandstones.		

The dip of these measures is 30° N., and the strike N. 91° E.

The base of the Chignik formation in the Herendeen Bay district is a surface of unconformity, the Chignik formation resting in some places on the Upper Jurassic rocks of the Naknek formation and in other places on the Lower Cretaceous rocks of the Herendeen limestone. This trangression, which, without making any allowance for the Jurassic strata involved, is at least 1,800 feet within a horizontal distance of 2 miles, or the equivalent of an average angular unconformity of 10°, is altogether too much to be accounted for as mere overlap. The contact of the Chignik formation with the overlying Tertiary rocks is stated by Atwood to be conformable.

The north shore of Kaguyak Bay, near Aievak or Douglas village, not far from the east end of the Alaska Peninsula, contains an almost unbroken series of outcrops of sedimentary rocks striking slightly north of west and dipping 15° N. The westernmost exposures consist of dark shale with marine Upper Cretaceous fossils (lot 3121). The rocks in the east end of the cliffs consist of gray sandstone with thinner beds of dark shale in which no fossils were found, except fragmentary plant stems and two specimens of dicotyledonous leaves that were too imperfect for identification. The high cliffs as seen from the water apparently show an unconformity

above the greater part of the section and below the leaf beds, but this unconformity was not detected in studying the exposures at the base of the cliffs. The total thickness of the strata in the cliffs was estimated at about 2,000 feet, of which the larger part is Cretaceous. The beds above the unconformity are probably Tertiary.

Another locality of Upper Cretaceous rocks on the Alaska Peninsula is indicated by the fossil identified by Grewingk[55] as *Belemnites paxillosus?*, which was collected by Wosnessenski "near Katmai." This fossil was regarded by Pompeckj[56] as an Upper Cretaceous *Belemnitella*. The other fossils collected by Wosnessenski are Middle and Upper Jurassic (see pp. 192, 203), and the precise locality of all of them is much in doubt.

Age and correlation.—The fossils from the Upper Cretaceous Chignik formation of the Alaska Peninsula are listed in the accompanying table. The collections from the type area of the Chignik formation are arranged approximately in stratigraphic sequence, beginning with the lowest. The first six lots from this area (5796, 11362, 5799, 3116, 5795, and 11361) are from the lower member, eight lots (5793, 3525, 3115, 3521, 5295, 3114, 5294, and 5797) are from the upper member, and the other two lots (5296 and 5297) are probably from the upper member. In this area the lower member has yielded only marine invertebrate fossils, the middle member has yielded no fossils, and the upper member has yielded both plants and marine invertebrates.

The fossils from the Chignik formation of Herendeen Bay can not be assigned to a position within the formation with as much confidence as the fossils from Chignik Bay. The lots from Mine Creek (3485, 3490, 3709, 3708, S. P. (c), 5184, and 539) all came from the general vicinity of the coal beds and probably came from the middle member ("coal measures") or possibly from the lower part of the upper member. However, the locality descriptions are vague, and it is possible that some of these fossils came from the lower member. These collections include both marine invertebrates and plants, but the shells and leaves were apparently not obtained from the same beds, nor have the relations of the plant beds to the strata carrying the shells been determined. The marine shells, according to Stanton, are clearly of Upper Cretaceous age. Some of the collections of plants have been regarded as Cretaceous and others as Tertiary, but most of them have previously been considered doubtful. The middle member yielded also lots 5185 and

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55 Grewingk, C., Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der nordwest Küste Amerikas, mit den anliegenden Inseln: Russ.-k. min. Gesell. St. Petersburg Verh., 1848–49, pp. 121, 347.

56 Pompeckj, J. F., Jura-Fossilien aus Alaska: K. russ. min. Gesell. St. Petersburg Verh., 2d ser., Band 38, No. 1, 1900, pp. 245, 268–270, 274, 276, 282.

5187, containing fossil leaves. The marine invertebrates in lots 5580, 5588, and 5577 were obtained not far below the Tertiary rocks, presumably from the upper member. They are, according to Stanton, undoubtedly Upper Cretaceous.

Lots 3121 and 5189 contain marine invertebrates and plants from two outlying localities near the east end of the Alaska Peninsula and on Pavlof Bay, respectively. Their position in the Upper Cretaceous sequence has not been determined, but they are believed to be in the upper member.

Fossils from the Chignik formation [a]

	Lower member						Middle member									Upper (?) member							Upper member						
	5796	11362	5799	3116	5795	11361	3485	3490	3709	3708	S. P. (c)	5184	539	5185	5187	5296	5297	5580	5588	5577	3121	5189	5793	3525	3521, 3115	5295	3114	5797	5294
Cladophlebis, n. sp															a										a				
Phegopteria, n. sp																										a			
Pteris, n. sp																	a												
Sagenopteris, n. sp														a															
Sagenopteris, n. sp														a															
Nilssonia serotina Heer										a				a	a		a							a	a	a			
Nilssonia, n. sp														a															
Ginkgo, n. sp													a	a	a		a								a	a			
Nageiopsis zamioides Fontaine?																										a			
Phyllocladites, n. sp																									a				
Cephalotaxopsis, n. sp																									a				a
Cephalotaxopsis, n. var															a		a								a				
Tumion?															a										a				
Sequoia rigida Heer?															a														
Sequoia obovata Knowlton									a								a					a							
Glyptostrobus? sp																									a				
Smilax, n. sp														a															
Populus hyperborea Heer?															a														
Populus, n. sp																	a												
Populus elliptica Newberry														a															
Populus, n. sp																	a												
Hicoria, n. sp														a															
Alnus, n. sp																									a				
Quercus, n. sp																	a												
Quercus, n. sp																									a				
Quercus, n. sp																									a				
Quercus, n. sp														a															
Dryophyllum bruneri Ward														a															
Ulmus, n. sp																									a				
Ulmus, n. sp														a															
Ficus laurophylla Lesquereux																						a							
Ficus?, n. sp																						a							
Urtica, n. sp																										a			
Urtica, n. sp															a		a												
Castaliites, n. sp														a															
Castaliites, n. sp														a															
Magnolia, n. sp																	a												
Persea hayana Lesquereux?																						a							
Sorbus, n. sp																									a				

Colutea primordialis Heer																					a								
Cusjacum, n. sp														a															
Celastrus, n. sp														a															
Celastrus, n. sp														a															
Rulac, n. sp															a									a	a				
Rhamnus, n. sp												a												a					
Paliurus, n. sp																								a					
Paliurus, n. sp																								a					
Zizyphus, n. sp																								a					
Zizyphus, n. sp																								a					
Zizyphus, n. sp																								a					
Vitis, n. sp																								a					
Grewia, n. sp														a															
Apeibopsis, n. sp														a															
Pterospermum, n. sp															a														
Trapa? microphylla Lesquereux																a													
Aralia, n. sp																					a								
Hedera macclurii Heer?																	a												
Hedera, n. sp																	a												
Cornus forchammeri Herr																	a												
Cornus, n. sp												a																	
Cornus, n. sp																								a					
Cornus, n. sp																	a												
Diospyros steenstrupi Heer																								a					
Diospyros, n. sp																								a					
Viburnum simile Knowlton?																								a					
Viburnum sp														a															
Phytoradicularia, n. sp										a																			
Rhynchonella?																										b	b		
Nucula (Acila) n. sp																										b			
Nucula																											b		
Yoldia, n. sp																										b	b		
Glycimeris veatchii Gabb	b	b	b		b																								
Inoceramus undulato-plicatus Roemer			b		b														b										
Inoceramus undulato-plicatus var. chignikensis Smith	b	b			b																								
Inoceramus (small species)		b																											
Inoceramus				c		b	c	c			c									b	c		c			b	c		
Unio?																								c					
Trigonia leana? Gabb				b																									
Trigonia																											c		
Pecten																										b			
Anomia, n. sp	b	b	b		b																								
Anomia				b															b										
Thracia?																										c			
Clisocolus cordatus Whiteaves	b																												
Meretrix, n. sp					b																								
Meretrix nitida Gabb	b	b	b		b																								
Tellina nanaimoensis Whiteaves?	b																												
Tellina, n. sp					b																								
Mactra (Cymbophoria) ashburnerii Gabb	b	b																											

[a] a, Identified by Arthur Hollick; b, identified by W. R. Smith; c, identified by T. W. Stanton.

Fossils from the Chignik formation [a]—Continued

	Lower member						Middle member									Upper (?) member							Upper member						
	5796	11362	5799	3116	5795	11361	3485	3490	3709	3708	S. P. (c)	5184	539	5185	5187	5296	5297	5580	5588	5577	3121	5189	5793	3525	3521, 3115	5295	3114	5797	5294
Corbula?																											b		
Pelecypods																												b	
Dentalium																											b	b	
Margarita, n. sp	b	b	b																										
Perissolax brevirostris Gabb	c				c																								
Fusus kingii (Gabb) Whiteaves var	b																												
Volutoderma	c																												
Cinulia																											c		
Desmoceras? cf. D. subquadratum Anderson																					c								
Pachydiscus cf. P. multisulcatus Whiteaves																		c											
Pachydiscus newberryanus Meek var	b																												
Pachydiscus			b																										
Hamites?																												c	
Anisoceras																											b		

[a] a, Identified by Arthur Hollick; b, identified by W. R. Smith; c, identified by T. W. Stanton.

5796 (52). North side of Chignik Bay 1 mile north of base of sand spit. W. W. Atwood, 1908.

11362 (36). Same locality as 5796. W. R. Smith, 1922.

5799 (58). Chignik Lagoon, nearly opposite Alaska Packers Association's cannery. W. W. Atwood, 1908.

3116 (959). Whalers Creek, about 1½ or 2 miles from the shore of Chignik Lagoon. Sandstone underlying the coal-bearing beds. T. W. Stanton and R. W. Stone, 1904.

5795 (51). Whalers Creek, about 2 miles from Chignik Lagoon. Series of sandstones about 100 feet below the coal. W. W. Atwood, 1908.

11361 (35). Head of creek that flows into Hook Bay. W. R. Smith, 1922.

3485 (a). Big exposure on left fork of Mine Creek, Herendeen Bay, just above coal. Sidney Paige, 1905.

3490 (b). About 200 yards above left fork of Mine Creek, Herendeen Bay. Sidney Paige, 1905.

3709. Right branch of Mine Creek, 200 feet above fork. Herendeen Bay. Sidney Paige, 1905.

3708 (4). Mine Creek, right branch below first side stream. Herendeen Bay. Sidney Paige, 1905.

S. P. (c). Just above Johnson tunnel, Herendeen Bay. Sidney Paige, 1905.

5184 (30). Mine Creek, Herendeen Bay. "Coal series." W. W. Atwood, 1908.

539. Cut on tramway, about a mile from the head of Mine Harbor, Herendeen Bay, within a few hundred yards of the mine. C. H. Townsend, 1890.

5185 (31). Coal Bluff, east shore of Herendeen Bay. "Coal series." W. W. Atwood, 1908.

5187 (35). Canyon 2 miles west of mouth of creek, about the middle of the west shore of Mud Bay, Port Moller. Shale bed. W. W. Atwood, 1908.

5296 (54). North shore of Chignik River just below Long Bay. W. W. Atwood, 1908.

5297 (55). North shore of Chignik River just below Long Bay. About 30 feet above 5296. W. W. Atwood, 1908.

5580 (23). Canyon on east face of Pinnacle Mountain near summit, near head of Herendeen Bay. W. W. Atwood, 1908.

5588 (38). West side of Buck Valley, about 1½ miles from shore of Herendeen Bay. W. W. Atwood, 1908.

5577 (18). Canyon north of Pyramid Peak, about 4 miles south of Herendeen Bay. W. W. Atwood, 1908.

3121. North shore of Kaguyak Bay, 1 mile east of mouth of river. G. C. Martin, 1904.

5189 (44). East side of Pavlof Bay. W. W. Atwood, 1908.

5793 (45). South shore of Chignik Bay just west of end of Chignik Head. W. W. Atwood, 1908.

3525 (963). East shore of Doris Cove, Chignik Bay. T. W. Stanton and R. W. Stone, 1904.

3521 (958). South shore of Chignik Bay, 2 miles northeast of Alaska Packers Association's cannery, opposite end of sand spit. Talus which evidently came from one of the shaly layers not far above the base of the exposure. T. W. Stanton and R. W. Stone, 1904.

3115 (958a). Same locality as 3521. Sandstone fragments in talus. T. W. Stanton and R. W. Stone, 1904.

5295 (49). South shore of Chignik Lagoon nearly opposite the end of the sand spit. Bed 4 of section on p. 297. W. W. Atwood, 1908.

3114 (957). South shore of Chignik Lagoon 200 yards southwest of native village, about 1 mile northeast of Alaska Packers Association's cannery. Dark shale. T. W. Stanton and R. W. Stone, 1904.

5797 (53). South shore of Chignik Lagoon, about 200 yards southwest of native village. Bed 1 of section on p. 297. W. W. Atwood, 1908.

5294 (48). Anchorage Bay, opposite Northwestern Fisheries cannery. W. W. Atwood, 1908.

The preceding table shows that the lower member of the Chignik formation has yielded only marine invertebrate fossils, the middle member has yielded fossil plants and a few marine mollusks (*Inoceramus*), and the upper member has yielded a considerable variety both of plants and marine invertebrates. The faunas and floras of the several members are distinctive. Only one species among the invertebrates extends over from one member into another. Among the fossil plants 68 per cent of all the species in the middle member, or 81 per cent of the angiosperms, and 78 per cent of all the species in the upper member, or 91 per cent of the angiosperms, are characteristic of the members.

Of the fossils from the lower member, the following have been found in other formations:

Glycimeris veatchi, in the Chico and Martinez.
Inoceramus undulato-plicatus, in the Austin and Niobrara.
Trigonia leana, *Mactra* (*Cymbophoria*) *ashburnerii*, and *Perissolax brevirostris*, in the Chico.
Meretrix nitida, *Fusus kingii* var., and *Pachydiscus newberryanus* var., in the Chico and Nanaimo.
Clisocolus cordatus and *Tellina nanaimoensis*, in the Nanaimo.

The fauna of the lower member, according to Stanton,[57] is certainly Upper Cretaceous and is "the Chico fauna of the Pacific coast, especially as developed in the Nanaimo formation of Vancouver Island." Concerning another collection of fossils from one of the same localities in the lower member Stanton [58] said:

> These fossils indicate correlation with a horizon in the Chico as developed in California and in the Nanaimo of Vancouver Island, which include practically all of the Upper Cretaceous, but the beds at Chignik are probably not older than basal Senonian.

Stanton [59] adds in explanation of this statement that he correlates the Niobrara formation of the Great Plains and the Austin chalk of Texas with the basal Senonian. Both of these formations contain *Inoceramus undulato-plicatus* Roemer, which is probably specifically identical with the form usually identified as *I. digitatus.*

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[57] Stanton, T. W., cited by Atwood, W. W., Geology and mineral resources of parts of the Alaska Peninsula: U. S. Geol. Survey Bull. 467, p. 43, 1911.

[58] Stanton, T. W., and Martin, G. C., Mesozoic section on Cook Inlet and Alaska Peninsula: Geol. Soc. America Bull., vol. 16, p. 408, 1905.

[59] Stanton, T. W., personal note.

The middle member of the Chignik formation has yielded the fossils listed in the table on pages 302–304. The only marine invertebrate species is an unidentified species of *Inoceramus*, which occurs more abundantly in the lower member and may occur also in the upper member. The fossil plants belong for the most part to species not yet described and do not furnish conclusive evidence as to the age of the member. The species that are known outside of the formation occur in rocks ranging in age from Potomac to Montana, but most of them are cycads and conifers from which a close determination of age can not be expected. The evidence of the fossil plants is not out of harmony with Stanton's assignment of the fauna of the lower member to a horizon in the Chico. Of the fossils listed in the table, the following have been found in other formations:

Nilssonia serotina, in the Gyliakian of Sakhalin.
Nilssonia n. sp. and *Cephalotaxopsis* n. var., in the Nulato and Kaltag.
Sequoia rigida, in the Potomac, Kome, Lower Atane, and Melozi.
Sequoia obovata, in the Montana and Vermejo.
Populus hyperborea and *Populus elliptica*, in the Dakota.
Dryophyllum bruneri, in the Mesaverde.

The upper member of the Chignik formation has yielded a large number of fossils, including both plants and marine invertebrates, which are listed in the table on pages 302–304. The fauna of the upper member is quite distinct from that of the lower member, only *Inoceramus undulato-plicatus* and an unidentified species of *Anomia* being possibly in common. Lot 5797, according to Stanton,[60] is "certainly Mesozoic and presumably Upper Cretaceous. The fossils indicate a different horizon, or at least a different facies, from the one represented at neighboring localities [in the upper member] from which Cretaceous collections were obtained." The flora of the upper member includes a large number of new species which are of no value at present in correlating. About half of the previously described species are known elsewhere in rocks of approximately Montana age, and the other half in rocks of older Cretaceous formations. The evidence of the fossil plants therefore suggests that the upper member of the Chignik formation belongs well up in the Upper Cretaceous, an assignment which is quite in harmony with the evidence of the marine invertebrates.

The fossils of the upper member known in other formations are listed below.

Nilssonia serotina, in the Gyliakian of Sakhalin.
Nageiopsis zamioides, in the Potomac.
Cephalotaxopsis n. sp., in the Melozi.
Cephalotaxopsis n. var., in the Molozi and Kaltag.

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[60] Stanton, T. W., cited by Atwood, W. W., op. cit., p. 44.

Sequoia obovata, in the Montana and Vermejo.
Ficus laurophylla and *Persea hayana*, in the Dakota.
Colutea primordialis and *Cornus forchammeri*, in the Magothy and lower part of the Atane.
Trapa? microphylla, in the Montana and Fort Union.
Hedera macclurii, in the Orokian of Sakhalin.
Diospyros steenstrupi, in the Patoot.
Viburnum simile, in the Vermejo.
Inoceramus undulato-plicatus, in the Austin and Niobrara.
Desmoceras? cf. *D. subquadratum*, in the upper part of the Horsetown.
Pachydiscus cf. *P. multisulcatus*, in the Nanaimo.

COOK INLET AND SUSITNA VALLEY

GENERAL FEATURES

The only rocks in the Cook Inlet-Susitna embayment that have been assigned to the Cretaceous, except the Cretaceous rocks of the Matanuska Valley, which will be described under a separate heading, are some supposed Upper Cretaceous slate and graywacke in the vicinity of Cache Creek, in the Yentna district. These beds are apparently several thousand feet thick, but their base and the underlying rocks have not been recognized. They are overlain unconformably by Tertiary lignite-bearing beds.

Cretaceous rocks may be present at other places in the Cook Inlet-Susitna embayment, as in and near Kenai Peninsula,[61] especially at the head of Crow Creek, on the north side of Turnagain Arm,[62] on the West Fork of Chulitna River,[63] on Susitna River,[64] and on Kichatna River.[65] There is, however, no proof that any of these rocks are Cretaceous, and they may not even be Mesozoic.

UPPER CRETACEOUS (?)

SLATE AND GRAYWACKE OF CACHE CREEK

The supposed Upper Cretaceous slate and graywacke of Cache Creek and vicinity were described by Capps[66] as "slate and graywacke series (Paleozoic or Mesozoic)." His account includes discussions of the distribution, character, structure, thickness, age, and correlation of the rocks, which had then yielded no fossils and could be only "provisionally assigned to the Paleozoic or Mesozoic."

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61 Martin, G. C., General features of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 33–35, 1915.

62 Johnson, B. L., The central and northern parts of Kenai Peninsula: U. S. Geol. Survey Bull. 587, pp. 118–119, 1915.

63 Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 217–218, 1919.

64 Eldridge, G. H., A reconnaissance in Susita basin and adjacent territory, Alaska: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 15–16, 1900.

65 Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 67–68, 1911.

66 Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, pp. 24–28, pl. 3, 1913.

These rocks were correlated by Capps with similar rocks observed by Brooks[67] in the valley of Kichatna River and with the Susitna slate described by Eldridge.[68]

These rocks were reexamined in 1917 by Mertie,[69] who described them briefly under the heading "slate and graywacke series." His account includes a brief general description, which is largely a summary of the description by Capps, references to the previous descriptions, and a brief discussion of the age of the rocks including a statement by Stanton concerning some fossils collected by Mertie.

In regard to the lithologic character of the slate and graywacke of the Cache Creek district, particularly in the Dutch and Peters hills, Capps[70] wrote as follows:

> They consist chiefly of black to gray slates and phyllites, in many places carbonaceous, and beds of graywacke, which range from fine-grained to coarse gritty rocks. In some places the rocks are massive, with argillites instead of slates, but the foliated types are much more widespread than the massive types. It is difficult to estimate just what proportion of the whole series is formed by the graywacke beds. Many sections show great thicknesses of the slaty phases, with very little graywacke present. At other localities the graywackes preponderate, occurring in thick, massive beds that show little foliation or schistosity and that are often mistaken by the miners for fine-grained dike rocks, which they closely resemble. The whole series is much jointed, the graywackes less closely than the slates, which are in many places broken into long prismatic pieces by sets of intersecting joints.

On account of the irregularity of structure and the lack of knowledge of these rocks over a large area, no reliable estimate of thickness can be made other than the statement, as given by Capps,[71] that the series is several thousand feet thick. The rocks beneath the slate and graywacke have not been recognized. The overlying rocks, which rest upon the slate and graywacke unconformably are Tertiary lignite-bearing beds.

The following statement was made by Stanton[72] concerning some fossils collected by Mertie in 1917:

> 10124. No. 4. Angular wash, half a mile from head of Long Creek, tributary of Tokichitna River. Elevation, 2,500 feet.
>
> 10125. No. 5. In place, a quarter of a mile from head of same creek. Elevation, 2,600 feet.
>
> These two specimens are fragmentary imprints in slate and probably represent a single species, which in my opinion is referable to a broad form of

[67] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 67–68, 1911.

[68] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 15–16, 1900.

[69] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 236–237, 1919.

[70] Capps, S. R., The Yentna district, Alaska: U. S. Geol. Survey Bull. 534, p. 25, 1913.

[71] Idem, p. 27.

[72] Stanton, T. W., cited by Mertie, J. B., jr., op. cit., p. 237.

Inoceramus more like some of the Alaskan Upper Cretaceous types of *Inoceramus* than those known from the Jurassic. It is probably worthy of mention that the lithology of the matrix suggests the Yakutat rocks of Woody Island and that the fossils themselves have some resemblance to *Inoceramya concentrica* Ulrich from that locality, though they do not belong to that species. Though other fossils are needed to make the identification positive, I think that these fossils are probably of Upper Cretaceous age.

MATANUSKA VALLEY

GENERAL FEATURES

The Cretaceous rocks of the Matanuska Valley include both Lower Cretaceous and Upper Cretaceous marine sedimentary strata. The Lower Cretaceous strata are somewhat but not altogether similar, both lithologically and faunally, to the Lower Cretaceous rocks of the Alaska Peninsula. The Upper Cretaceous beds are especially well developed, comprising several thousand feet of strata that crop out over a wide area. They contain a fauna that is similar to that of the Upper Cretaceous beds of the Alaska Peninsula, but they differ strikingly from those beds in that they include neither coal beds nor the characteristic Upper Cretaceous flora.

The general sequence is as follows:

General section of Cretaceous strata in Matanuska Valley

	Feet
Upper Cretaceous (overlain unconformably by nonmarine Tertiary deposits):	
Matanuska formation:	
Sandstone and shale, sparsely fossiliferous	2,100
Shale with some sandstone. Carries an abundant marine invertebrate fauna	2,000±
Unconformity (?).	
Lower Cretaceous:	
Nelchina limestone (massive dark-colored fine-grained unaltered limestone with *Belemnites*)	300±
Conglomeratic tuff and arkose, with *Aucella crassicollis*	100–200
Conformity (?), with Upper Jurassic strata beneath.	

LOWER CRETACEOUS

CONGLOMERATIC TUFF AND ARKOSE

Historical review.—The tuff and conglomerate which are seemingly the basal Lower Cretaceous strata of the Matanuska Valley were included by Mendenhall in the thick and heterogeneous aggregate of strata described as the "Matanuska series." Mendenhall gave no published description of the tuff and conglomerate, although they were apparently the source of the fossils on the basis of which the "Matanuska series" was referred to the Lower Creta-

ceous.[73] It should be noted that Mendenhall's statement that the fossils "were collected at the base of the limestone" does not mean, as has been generally assumed, that the fossils were obtained from the limestone, for both Mendenhall's field notes and the character of the matrix in which the fossils are embedded clearly show that the fossils were obtained from the conglomerate tuff or arkose beneath the limestone.

The first published statement regarding the character of these fossiliferous beds consists of a brief description quoted by Martin[74] from Mendenhall's field notes.

These beds were included in the Upper Jurassic by Paige and Knopf,[75] who described them as the strata on Billy Creek containing "interstratified tuff beds" and arkose. This account contains a detailed petrographic description of the tuff, with statements as to the general stratigraphic relations and the probable origin of the sediments.

The description of these beds by Martin and Katz[76] consists of a quotation of the account by Paige and Knopf, with the exclusion of part of the petrographic description.

These rocks were mapped by Chapin[77] as part of the Naknek formation, but no description of them was given.

Stratigraphic description.—The Lower Cretaceous rocks of the Matanuska Valley and of the adjacent headwater area of the Nelchina Valley apparently include at their base highly fossiliferous tuff or arkose and conglomerate. These rocks are well exposed in Limestone Gulch and on the neighboring tributaries of Billy Creek and of Nelchina River, where their thickness was estimated by the writer to be between 100 and 200 feet. These beds overlie the Upper Jurassic sandstone and shale described on page 230 with apparent conformity, unless their conglomeratic character is in itself evidence of unconformity. They are overlain, probably conformably, by the Lower Cretaceous limestone described on page 314.

The strata beneath the limestone are well exposed on the eastern tributary of Billy Creek that heads in Limestone Gap. At this place, according to the writer's observations, the beds 100 feet below the limestone are conglomeratic and are highly fossiliferous, the fossils of lot 8580 (p. 313) having been obtained at this horizon. No

[73] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 309, 1900.

[74] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: U. S. Geol. Survey Bull. 289, p. 11, 1906.

[75] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, p. 21, 1907.

[76] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 21, 1912.

[77] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, pl. 2, 1918.

change in lithologic character was noted between this fossil bed and the base of the overlying limestone. The next lower bed concerning which observations were recorded is a stratum of sandstone, about 200 or 300 feet below the limestone, which yielded the Upper Jurassic fossils of lot 8579 (p. 232). The strata exposed in this gulch were described by Paige and Knopf[78] as follows:

On Billy Creek a number of interstratified tuff beds from 1 to 4 feet thick occur near the top of the series, a few hundred feet beneath the base of the Cretaceous. These tuffs differ greatly in appearance from the older Jurassic tuffs. They consist largely of fragments of glassy, striated feldspar, hornblende, and quartz with fine pyramidal terminations, set in an almost black matrix. Belemnites and lamellibranchs are embedded in these tuffs. Higher in the series arkoses, closely simulating granites in appearance, are interstratified with the sandstones. Coarser phases contain pieces of a fresh granitic rock—a hornblende-biotite-quartz monzonite. The arkose is composed largely of rounded and angular fragments of feldspar in a more or less advanced state of alteration. Quartz is notably absent. Deep-brown hornblende is somewhat common, and a few flakes of strongly pleochroic biotite are found. With these are associated fragments of hornblende andesite, highly altered, some of which were noted to contain large idiomorphic feldspars similar to those forming the bulk of the rock. The arkose thus appears to have been derived principally from the destruction of a volcanic land mass, but some of its material was possibly brought from a monzonite area, as indicated by the fragments of monzonite. Under the microscope the feldspars of these arkoses by their alteration contrast strongly with the clear, glassy feldspars of the somewhat older crystal tuffs already described.

The exposures of these same strata on the headwaters of Nelchina River, 1 or 2 miles east of this gulch, were described by Mendenhall[79] as follows:

In the head of the stream rising on the east side of Limestone Gap, at the beginning of the limestone gorge about a mile from the gap, is a curious exposure of mingled conglomerate and fossil-bearing rocks. The shells [lot 2046, p. 313] are embedded in a sand matrix and are often only casts. These beds are at the base of the limestone as exposed here. The limestone, however, seems to be high up in the sedimentary series. The limestone lies in a syncline, at the deepest point of which the fossils were gathered. East of this dips are westward and rocks mostly soft shale.

Age and correlation.—The fauna of the supposed Lower Cretaceous tuff and conglomerate of the Matanuska and Nelchina Valleys is very meager and does not fix the age of those beds with absolute certainty. Stanton[80] made the following statement regarding the fossils collected by Mendenhall:

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[78] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, p. 21, 1907.

[79] Mendenhall, W. C., field notes quoted by Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: U. S. Geol. Survey Bull. 289, p. 11, 1906.

[80] Stanton, T. W., cited by Mendenhall, W. C., op. cit. (Twentieth Ann. Rept., pt. 7), p. 309.

The fossils * * * have been examined and found to consist of numerous examples of *Aucella crassicollis* Keyserling and a few fragments of a large *Belemnites* which can not be identified specifically. The species determined is sufficient to fix the age of the bed from which they came as Lower Cretaceous.

Concerning the *Aucella* collected by the writer (lot 8580) at presumably the same horizon, Stanton[81] said:

This is the same large species which was identified as *A. crassicollis* Keyserling in Mendenhall's collection from Bubb Creek. While this Alaskan species may not belong to *A. crassicollis* as restricted by the Russian paleontologists, who recognize a very large number of species of *Aucella,* it does belong to a group of forms which is most abundant in the Lower Cretaceous and is therefore suggestive of Cretaceous age, though the possibility that *Aucella* may have attained the same development locally during late Jurassic time must be kept in mind.

The Mendenhall collection of this species was collected at the base of a 200 to 400 foot bed of white limestone according to the label, but the dark sandy matrix attached to the fossils shows that they did not come from the limestone itself.

The fossil localities are listed below. *Aucella* cf. *A. crassicollis* was found at both, and locality 2046 yielded also *Belemnites.*

8580. Limestone Gulch, tributary of Billy Creek. Conglomeratic and sandy beds 100 feet below base of limestone. G. C. Martin, 1913.

2046. About 1 mile east of Limestone Gap, near headwaters of a tributary of Nelchina River. Sandy matrix of a conglomerate at the base of the limestone. W. C. Mendenhall, 1898.

NELCHINA LIMESTONE

Historical review.—The rocks to which the name Nelchina limestone is herein applied, from their exposure on the hilltops at the headwaters of Nelchina River, were first described by Mendenhall[82] as an unnamed member of the "Matanuska series." This description includes only a brief statement concerning the occurrence and thickness of the limestone, which was referred to the Lower Cretaceous on the basis of Stanton's determination of the fossils obtained just below the base of the limestone in the underlying conglomeratic tuff. (See pp. 310–313.)

A description compiled wholly from the above-mentioned account by Mendenhall and from Mendenhall's field notes was published in 1906.[83]

This limestone was described as "Lower Cretaceous limestone" by Paige and Knopf,[84] whose account consists of a brief statement of the occurrence, thickness, and lithologic character.

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[81] Stanton, T. W., quoted by Martin, G. C., unpublished report on the geology of the upper Matanuska Valley.

[82] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 308, 309, 1900.

[83] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: U. S. Geol. Survey Bull. 289, pp. 10, 11, 1906.

[84] Paige, Sidney, and Knopf, Adolph, Stratigraphic succession in the region northeast of Cook Inlet, Alaska: Geol. Soc. America Bull., vol. 18, p. 330, 1907.

A more detailed description, based upon the same field observations, was afterwards given by the same authors,[85] who were the first to map the areal distribution of this limestone or to give a definite description of its stratigraphic occurrence. This account includes a brief statement concerning the stratigraphic relations of the limestone and a fairly detailed description of its lithologic character.

The description of this limestone by Martin and Katz[86] consists of a practically unmodified quotation of the detailed account by Paige and Knopf.

Martin and Katz also described,[87] as the probable equivalent of this Lower Cretaceous limestone, a crystalline limestone of doubtful age occurring in the lower part of the Matanuska Valley. (See pp. 315–316.)

The occurrence of this limestone in the Nelchina Valley has been mentioned briefly by Chapin.[88]

Stratigraphic description.—The Nelchina limestone occurs in several isolated areas, mostly small, on the hilltops at the headwaters of Nelchina River and of Billy Creek. It consists of massive dark-colored fine-grained unaltered limestone. Some beds are highly siliceous and probably ought to be called calcareous sandstone. The massive limestone beds are separated by thin laminae of gray shale. The thickness is at least 100 feet and may possibly be as much as 300 or 400 feet. The maximum thickness is difficult to determine with certainty, as there are indications of repetition by faulting where the limestone appears thickest. At some places there appear to be two massive limestones separated by several hundred feet of shale, but it is believed that this condition is due to faulting. The limestone overlies, with apparent conformity, the Lower Cretaceous tuff and conglomerate described on pages 310–313. Most of its observed occurrences are on hilltops where no overjoying rocks are present and where part of the original thickness of the limestone has been removed by erosion. At some places, notably in the hills west of Billy Creek, the limestone is overlain unconformably by a Tertiary conglomerate. The Upper Cretaceous strata that crop out on Billy Creek, as described on page 321, were not observed in contact with this limestone.

The description of this limestone given by Paige and Knopf[89] is as follows:

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[85] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 10, 24, pl. 2, 1907.

[86] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 15, 22–23, pl. 3, 1912.

[87] Idem, pp. 22, 32–33, pl. 5.

[88] Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, p. 38, pl. 2, 1918.

[89] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, p. 24, 1907.

Rocks of Lower Cretaceous age are represented mainly by a single formation—a massively bedded limestone, 300 feet thick, which overlies the Upper Jurassic strata conformably. The limestone has a limited areal distribution and is known only from the headwaters of Billy Creek and Nelchina River, where it weathers in prominent gray cliffs encircling the hilltops. The limestone is white and of very finely saccharoidal texture. On fresh fracture it emits a strong fetid odor. It is readily soluble in cold hydrochloric acid and evolves an abundance of unpleasant hydrocarbon gases. Qualitative tests show the presence of not more than a trace of magnesia. Under the microscope the detrital organic origin of this limestone is readily apparent. It is largely composed of irregular granules of dirty-looking calcite, but with these are associated numerous prismatic sections referable to organic fragments. Rhombohedral cleavage is here and there finely developed, but the characteristic calcite twinning is notably absent. Some of the carbonate is still in the aragonite form, as is indicated by negative biaxial interference figures. Accessory constituents are limpid plagioclase, quartz with hairlike rutile, hornblende, and, more rarely, augite and apatite. The incomplete conversion of the carbonate to the stable modification and the absence of twin lamellation in the calcite indicate the essentially static conditions in which the limestone has remained since its formation.

Age and correlation.—The Nelchina limestone seems to be in general remarkably unfossiliferous, although belemnites were seen in some of the thin strata of shale between the massive limestone beds. A large number of fragmentary belemnites were obtained from the residual soil lying on the surface of the limestone in one of the hilltop areas. They apparently could have been derived from no other possible source than the limestone or one of the thin shale strata interbedded with it.

The following statement concerning these fossils was furnished by T. W. Stanton:

8582. Limestone hills east of Billy Creek. Residual soil on the surface of the limestone. G. C. Martin, 1913. *Belemnites* sp., very large, stout form. This species suggests Jurassic rather than Cretaceous.

LIMESTONE NORTH OF CASTLE MOUNTAIN

The limestone in the lower Matanuska Valley north of Castle Mountain, as described by Martin and Katz,[90] occurs in a belt within which there is one large area and at least three smaller ones. The best exposures are on the ridge north of the west end of Castle Mountain, where the limestone is blue and gray to white and of fine to medium grain or degree of crystallinity. It is much shattered and full of minute calcite veins. Where seen on top of the ridge it is well bedded in strata from 6 inches to several feet thick, there being no decided change in lithologic character from bed to bed. The thickness is probably several hundred feet. The westernmost

[90] Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 32–33, pl. 5, 1912.

exposure on top of the ridge, a small, isolated outcrop at an altitude of about 4,700 feet, contains beds that are decidedly cherty.

The limestone on the crest of the ridge north of Castle Mountain lies in a closely compressed overturned syncline and rests upon somewhat altered volcanic rocks that are considered to be the same as the Lower Jurassic tuff of Chickaloon River, with which they are areally continuous. An exposure on the west end of this ridge shows the volcanic rocks in direct contact with the limestone. Small pebble-like fragments of the greenstone are embedded in the lower 2 inches of the limestone. These fragments give evidence that the limestone overlies the greenstone unconformably.

As no fossils have been found in the limestone north of Castle Mountain, the determination of its age must depend on the local stratigraphic evidence and on correlation with the rocks of neighboring regions.

It has been shown above that the limestone rests unconformably upon supposed Lower Jurassic rocks. The Middle and Upper Jurassic rocks of the upper part of the Matanuska Valley show a complete sequence of several thousand feet of strata in which limestone is absent. These Upper Jurassic rocks are overlain, on Billy Creek and Nelchina River, by Lower Cretaceous rocks, which, as described on pages 313–315, include a massively bedded limestone about 300 feet thick.

Although there are differences in the features of the two limestones they are such as might be explained by the fact that the two occurrences are 25 miles apart and in structurally different areas. These limestones consequently were provisionally correlated by Martin and Katz[91] and were referred to the Lower Cretaceous.

The correlation of the limestone north of Castle Mountain with the Lower Cretaceous Nelchina limestone must still be regarded as highly probable although not established beyond all doubt. If the altered volcanic rocks north of the west end of Castle Mountain, on the tributaries of Kings River, are of the same age as the less altered Lower Jurassic tuff on Chickaloon River, with which they are areally continuous, then the limestone north of Castle Mountain, which overlies these volcanic rocks unconformably, is certainly younger than Lower Jurassic and is probably Lower Cretaceous. If, however, the altered volcanic rocks of Kings River are not the same as the Lower Jurassic tuff of Chickaloon River, then there is no evidence that this limestone is Lower Cretaceous. In that case the limestone and the underlying volcanic rocks may possibly be correlated with the Upper Triassic Chitistone limestone and the underlying Nikolai greenstone of the Chitina Valley. (See pp. 7–18.)

[91] Op. cit., p. 33.

UPPER CRETACEOUS

MATANUSKA FORMATION

Historical review.—Upper Cretaceous strata have a broad extent and attain a great thickness in the Matanuska Valley, but they apparently constitute only a single formation which, so far as now known, is entirely of marine sedimentary origin. To these strata the name Matanuska formation is here applied.

The Upper Cretaceous rocks of the Matanuska Valley were first observed by Mendenhall in the course of a rapid exploratory journey in which the opportunities for stratigraphic observations were very scanty. Mendenhall included these Upper Cretaceous rocks in his "Matanuska series," which as originally described[92] comprised all the sedimentary rocks seen by him in the Matanuska and Nelchina Valleys. The "Matanuska series" was assigned by Mendenhall to the Lower Cretaceous because it was supposed to include the fossiliferous Lower Cretaceous conglomerate tuff of the headwaters of Nelchina River, which is described on pages 310–313. The "Matanuska series" as originally described is now known to have included a thick and heterogeneous aggregate of sedimentary and pyroclastic strata ranging in age from Lower Jurassic to late Tertiary. Mendenhall mentioned but did not specifically describe the strata now known to be Upper Cretaceous and herein designated the Matanuska formation. It happens, however, that the larger part of the area which was supposed to be occupied by the original "Matanuska series" contains these Upper Cretaceous strata, and that nearly all the exposures on the banks of Matanuska River from its source to its mouth consist of these Upper Cretaceous rocks. It is consequently believed to be appropriate to revive this long-abandoned name as the Matanuska formation, although it must be given a very different definition and assigned to a different position from that of the original "Matanuska series."

The Upper Cretaceous shale and sandstone of Anthracite Ridge were described briefly by Martin[93] as the result of a hasty reconnaissance of the coal fields of the lower part of the Matanuska Valley in 1905. The description is very brief and includes merely a not altogether accurate statement concerning the lithologic character of the rocks, which were represented on the geologic map[94] as "Mesozoic slate and graywacke," together with a statement by T. W. Stanton concerning two small collections of fossils that "so far as can be determined from these specimens the horizon may be as low as Middle

[92] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 307–309, 1900.

[93] Martin, G. C., A reconnaissance of the Matanuska coal field, Alaska, in 1905: U. S. Geol. Survey Bull. 289, p. 11, 1906.

[94] Idem, pl. 3.

Jurassic or as high as Upper Cretaceous," but on comparing them with the later and more extensive collections (see p. 236) he has assigned them definitely to the Upper Cretaceous. The other Upper Cretaceous areas in the lower part of the Matanuska Valley were mapped by Martin as part of the "Tertiary shale, sandstone, and conglomerate."

The Upper Cretaceous strata of the Matanuska Valley were not recognized as such by Paige and Knopf, who did not distinguish them from the somewhat similar Tertiary and Jurassic shale and sandstone. The geologic map by Paige and Knopf[95] consequently represents the areas now known to be occupied by this formation as partly Tertiary and partly Jurassic.

The presence of Upper Cretaceous rocks in the Matanuska Valley was first recognized by Martin and Katz,[96] who described and mapped in detail the occurrence of these rocks in the lower part of the valley. This account includes a general description of the formation, detailed descriptions of the section exposed on Granite Creek and of several other exposures, and lists of the marine invertebrate fossils, with a discussion of the age and relationships of the fauna by T. W. Stanton. The account includes also a list, by Arthur Hollick, of some fossil plants from beds which may belong in this formation but which Hollick considered to be probably Tertiary. (See p. 323.)

The Upper Cretaceous shale and sandstone at the headwaters of Squaw, Alfred, and Billy creeks were mentioned briefly by Chapin.[97]

Stratigraphic description.—The Upper Cretaceous rocks of the Matanuska Valley here designated Matanuska formation consist of shale and sandstone, having an aggregate thickness, as exposed on Granite Creek, of at least 4,000 feet, of which the lower half is practically all shale and the upper half consists of alternating beds of sandstone and shale, the sandstone predominating. Conglomerate is present but not in thick or numerous beds. The most complete section observed is in the gorge of Granite Creek and is recorded on pages 319–320. Other good sections are exposed on Kings River between the main trail and the coal camp and in the cliffs of Matanuska River. Many of these cliffs are not accessible for close study except at a very low stage of the water.

The base of the Upper Cretaceous shale has nowhere been observed, and there is much uncertainty not only as to the character of the basal contact but as to the identity of the underlying rocks.

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95 Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pl. 2, 1907.

96 Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 15, 23, 34–39, pls. 3, 5, 1912.

97 Chapin, Theodore, The Nelchina-Susitna region, Alaska: U. S. Geol. Survey Bull. 668, p. 38, pl. 2, 1918.

The distribution of the formation, relative to that of the older rocks of this region, indicates that it probably rests unconformably upon a surface of profound erosion cut across rocks ranging in age from Lower Jurassic to Lower Cretaceous.

The Upper Cretaceous sandstone is overlain unconformably by Tertiary arkose and conglomerate. The strongest evidence of the unconformity is found in the mountains west of Kings River, where the Tertiary rocks lie horizontally upon the surface of the presumably early Mesozoic granite within a quarter of a mile of a place where the Upper Cretaceous sediments are present in full development with the granite faulted against them.[98] It is therefore evident that as the Tertiary rocks directly overlie the pre-Cretaceous granite, at least the full thickness of the Upper Cretaceous sediments must have been removed at this place during the Cretaceous-Eocene erosion interval. At the coal camp on the east bank of Kings River the Tertiary coal-bearing rocks apparently rest unconformably across the upturned edges of the Upper Cretaceous sandstone, but as the coal-bearing beds exposed at this place are believed not to be the basal Tertiary rocks, this contact is considered a thrust fault rather than an unconformity.

The section on Granite Creek was measured in the gorge that begins 1¾ miles above its mouth and extends northward for 2 miles; in this distance exposures are almost continuous on one or the other bank, and in some places on both banks of the stream. It is assumed, in accepting this section and thickness, that there is no repetition of the beds by faulting. The exposures are not of such a character as to make this an absolutely safe assumption, although the absence of observed faults, or of beds that seem to be repeated, and the fact that the ridge on the east of the gorge presents an unbroken dip-slope suggest that the section is an uninterrupted and unrepeated monoclinal succession of beds.

The rocks exposed in the gorge of Granite Creek consist of southeastward-dipping sandy shale and flaggy sandstone. *Inoceramus* and other Upper Cretaceous fossils were collected from the shale of the lower part of the section, in the positions indicated. The sandstone, which predominates higher in the section, yielded no fossils except a fragmentary nuculoid form. No plant fossils were seen.

Section of Matanuska formation on Granite Creek, beginning at lower end of canyon, 1¾ miles from the mouth of the creek

	Feet
Black shale at base, overlain by thin-bedded gray sandstone, some of which is very fine and has contorted laminae, and gray or drab-gray shale (beds are interleaved lenses rarely more than 6 inches thick)	12
Black sandy shale	4–6

[98] See U. S. Geol. Survey Bull. 500, pl. 16, section H–H′, 1912.

	Feet
Thin-bedded gray sandstone and shale	15
Black nodular shale	8
Sandstone, mainly beds about 5 feet thick, with thin interbedded shale	30
Interbedded black shale and thin gray sandstone and shale	50
Massive sandstone, feldspathic and micaceous	20
Interbedded gray shale, gray sandstone, and black shale	40
Sandstone	12
Alternating beds, 1 to 8 feet thick, of gray sandy shale and black shale	250
Similar beds increasingly to dominantly sandy and light gray	80
Dark-colored sandstone and sandy shale	75
Light-gray sandstone, including several thick, massive beds and some very thin shale (in east bank; estimated thickness)	200
Dark shale in beds alternating with thin sandstone and light-colored shale	450
Sandstone, heavy bedded at the top but dominantly thin bedded (beds 1 to 2 feet and less than 1 foot), with many beds of very thin shaly sandstone having contorted laminae; also a few thin shale beds and an increasing number of beds of dark shale in the lower part	840
Exposures interrupted and inaccessible for 1,500 feet along the creek, equivalent to an estimated stratigraphic interval of	500
Dark bluish-black sandy shale outcropping for 200 feet in a direction about N. 17° E.; strike, N. 40° E.; dip, 60° SE.; computed thickness	80±
Exposure interrupted and inaccessible for 800 feet along the creek, equivalent to an estimated stratigraphic interval of	300±
Hard dark blue-black shale,[99] outcropping for about 200 feet in a direction N. 17° E.; strike, N. 28° E.; dip, 60° to 65° SE.; computed thickness	90±
Exposure interrupted and inaccessible for about 200 feet along the creek, equivalent to an estimated stratigraphic interval of	90±
Hard dark blue-black shale,[99] outcropping for 400 feet along the creek in a direction N. 17° E.; strike, N. 47° E.; dip, 50° SE.; computed thickness	170±
Exposure interrupted and inaccessible for 100 feet along the creek, equivalent to an estimated stratigraphic interval of	45±
Hard dark blue-black shale,[99] outcropping for about 1,000 feet along the creek; estimated thickness	400±
	3,760±
No exposure for 7,500 feet.	
Several small outcrops through 1,200 feet along the east bank of the creek in a northerly direction; strike, N. 23° E.; dip, 49° SE.; computed thickness	350±

[99] Fossils collected from these beds are lot 6689; see p. 324.

The Upper Cretaceous rocks (Matanuska formation) of the upper part of the Matanuska Valley are of the same general lithologic character as those in the lower part of the valley. In the belts that extend along the river the folding is so severe that no stratigraphic sequence can be recognized, the bedding in many places being destroyed. The same condition holds in general, though to a somewhat less degree, in the Anthracite Ridge and western Boulder Creek areas. Much more gentle structure exists on Alfred and Billy creeks and on the upper part of Boulder Creek, where the Upper Cretaceous rocks dip at low angles and have not been crumpled or crushed.

The exposures on Alfred Creek reveal several hundred feet of fissile drab shale that is sparsely fossiliferous. The rocks dip 5°–15° S. above the mouth of North Fork and 5°–10° N. below that place. They thus apparently lie in a shallow syncline in which several hundred feet of strata are exposed.

The rocks exposed on Billy Creek consist of blue sandy shale with abundant fossils (lot 8578, p. 324). The beds are horizontal, and as the observed exposures are restricted to low cliffs bordering the creek, a very small section is visible. The total thickness exposed, including the soil-covered beds, probably does not exceed 300 or 400 feet. The overlying beds are believed to be Tertiary conglomerate, resting unconformably upon the Upper Cretaceous and older strata.

The Upper Cretaceous rocks on the upper part of Boulder Creek include about 200 feet of shaly sandstone with *Inoceramus* (lot 8577, p. 324). A bed of conglomerate about 100 feet thick overlies this sandstone and is in turn overlain by at least 400 feet and possibly 600 or 800 feet of poorly indurated shale and sandstone with coal beds. These carbonaceous beds carry fossil plants, which are clearly of Tertiary age. The field relations also indicate that the conglomerate is at the base of the local Tertiary sequence.

Age and correlation.—Marine molluscan remains are fairly abundant in the shale that constitutes the lower half of the Matanuska formation. They show that it is undoubtedly of Upper Cretaceous age. Stanton[1] made the following statement regarding the age and relations of the fauna represented by the material collected by Martin and Katz in 1910:

Of the lots referred to the Upper Cretaceous those numbered 6689, 6694, and 6696 are certainly of that age and belong to the Upper Cretaceous fauna which has been recognized at several points on the Alaska Peninsula and is part of the general Indo-Pacific fauna found in the Chico formation of Cali-

[1] Stanton, T. W., quoted by Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley Alaska: U. S. Geol. Survey Bull. 500, pp. 38–39, 1912.

fornia, on Vancouver Island, in Japan, and in India. Most of the other lots in this collection, referred to the Cretaceous, contain only fragmentary specimens of *Inoceramus* which are not sufficient in themselves for discrimination between Jurassic and Cretaceous, though it is probable that these fragments belong to the same species that occurs at other localities in the neighborhood where the Cretaceous age of the rocks is definitely determined.

The following statements were made by Stanton [2] concerning some of the individual lots of fossils:

This collection [6696] is clearly of Upper Cretaceous age and belongs to the general Indo-Pacific fauna, which is well developed in India, Japan, Sakhalin, Vancouver, and California.

Inoceramus sp. [in lot 6689 is a] very large compressed form which has been collected [see 3121, p. 303] on Alaska Peninsula north of Aievak or Douglas village.

An unpublished report contains the following further comments by Stanton: [3]

The *Inoceramus* referred to *I. digitatus* in this list [8596] is the same species that has been so identified by Whiteaves from Vancouver Island. But according to H. Wood's recent monograph of the Cretaceous Lamellibranchiata of England the type of Sowerby's imperfectly known *Inoceramus digitatus* is a different species, and forms such as this are referred to *I. undulato-plicatus* Roemer.

A reexamination of lots numbered 3318 and 3319 in earlier collections from the Matanuska Valley and comparison with more recent collections was made, and they can now be definitely referred to the Upper Cretaceous.

Knopf's collections from the same regions were also reviewed, and his No. 6AK42 may possibly be Cretaceous, but it is still believed to be more probably Middle Jurassic. The matrix is not like that in which the Cretaceous fossils from that area are embedded but is a pebbly sandstone.

The higher sandy beds contain only rare and poorly preserved mollusks, chiefly *Inoceramus* and a few uncharacteristic nuculoid forms, together with some fossils of more or less problematic character that may be fucoids (*Spirophyton?*) and worm tracks or burrows, and possibly at one locality (5898) some leaves of rather uncertain age.

The problematic fossils (5893, 5894) occur in immediate association with a large form of *Inoceramus* (6691) and are thus known to be Mesozoic, and as they are apparently found above the horizons at which the more characteristic Upper Cretaceous fauna occurs, they are consequently Upper Cretaceous also. They are not sufficiently characteristic to yield of themselves any important independent evidence on the age of the rocks.

Fossil plants (lot 5898), which consist of species unlike those in the local Tertiary formations, were collected from beds that were

[2] Stanton, T. W., quoted by Martin, G. C., and Katz, F. J., op. cit., p. 37, 1912.

[3] Stanton, T. W., quoted by Martin, G. C., manuscript report on the geology of the upper Matanuska Valley.

regarded as occurring in the upper sandy part of the Matanuska formation but that are stratigraphically above the highest observed beds containing the marine Cretaceous fauna. These plant-bearing beds apparently are lithologically identical and stratigraphically conformable with the highest recognized Cretaceous rocks and are lithologically unlike any of the known Tertiary beds of this region. These beds are considerably more indurated than any of the local Tertiary rocks except those that have been involved in the intense deformation in the mountain region north of the Matanuska Valley. It is possible, however, that this condition is due to the position of these rocks near an intrusive contact. The field relations consequently indicate though they do not prove that this flora is older than the Tertiary floras described below and suggest that it belongs in the Upper Cretaceous. The flora is somewhat different in character from the known Tertiary floras but is, nevertheless, more like them than it is like any known Mesozoic floras.

The following report on this collection was made by Arthur Hollick:[4]

5898. Locality (34) at south of pond on top of mountain between Kings River and Young Creek, 1⅛ miles N. 10° W. from Kings River Bridge:

Equisetum arcticum Heer? Specimens very fragmentary. Some pieces might equally well be referred to E. robustum Newberry.

Glyptostrobus ungeri Heer? Fragmentary remains of a heterophyllous conifer, some of which might equally well be referred to Juniperus tertiaria Heer.

Nyassa arctica Heer.

Aristolochia sp. This is in great abundance and is very variable in form. Some specimens are hardly to be distinguished from certain forms of Populus arctica Heer.

This is a meager and more or less unsatisfactory collection. The general facies is different, however, from that of any other collection from the Matanuska field. Age, basal Eocene.

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[4] Hollick, Arthur, quoted by Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, p. 38, 1912.

Upper Cretaceous fossils from Matanuska formation of Matanuska Valley [a]

	6690	6695	6696	6689	6705	6692	6699	6700	6702	6703	6694	6691	5893, 5894	6701	6704	8559	8568	8560	8562	8563	8566	3318	3319	8577	8596	8595	8592	8598	(48)	8594	8591	8947	8948	8586	8587	8590	8578
Spirophyton?													b																								
Coral																	c																				
Trails or burrows													b								a					c											
Echinoid spines?																													a								
Echinoid							a																														
Discina?																			c																		
Rhynchonella																																		c			
Rhynchonella?				a		a																															
Nucula																						a															
Nemodon																			c																		c
Nemodon?			a																												c						
Inoceramus cf. I. labiatus Schlotheim				a												a																					
Inoceramus n. sp																			c	c																	
Inoceramus undulato-plicatus Roemer																									c						c						
Inoceramus (very large compressed form)				a							a																										
Inoceramus (probably young of the last)			a																																		
Inoceramus (large flat species)												a																									
Inoceramus	a	a			a	a		a	a	a				a	a	c	c	a	a	c		a	a	c	c	c	a	a		c	c	a		c			c
Ostrea											a								c				a								a						
Ostrea?																													a								
Pecten, n. sp.?																									c												
Anomia, n. sp																															c						
Thracia?																	c																				
Astarte																			c	c																	
Corbula																			c																		
Pleurotomaria																																		c			
Amberleya			a																																		
Lunatia?																c																					
Mesostoma?																															c						
Gastropods																			c																		
Phylloceras, n. sp																			c																		
Phylloceras ramosum (Meek)?																c																					
Phylloceras ramosum Meek var																	c		c																		
Phylloceras cf. P. ramosum Meek																																				c	
Phylloceras			a																																		
Tetragonites timotheanus Mayor																			c																		
Gaudryceras kayei Forbes var																	c			c																	
Gaudryceras, n. sp																			c																		
Desmoceras sugata Forbes?			a																																		
Desmoceras?			a																																		
Pachydiscus			a																																		
Baculites chicoensis (Trask) Gabb?																c			c																		
Baculites																				a														c			c

Diplomoceras notabile Whiteaves																																					c
Diplomoceras notabile Whiteaves?											a					c			c							c											
Diplomoceras																			c																		
Lytoceras																	a																	c			
Hamites																c			c																		
Hamites?																							a				a										
Heteroceras?																																	a				
Anisoceras cooperi Whiteaves var.																																			c		
Anisoceras, n. sp.																			c																		
Anisoceras subcompressum Forbes?																			c																		
Anisoceras?			a																																		
Ammonite (very young)																							a														
Belemnites																							a														
Belemnites or Belemnitella																																					a

[a] a, Identified by T. W. Stanton; b, identified by Arthur Hollick; c, identified by W. R. Smith.

6690. North bank of Matanuska River at lower end of canyon about a mile above Moose Creek. G. C. Martin, 1910.

6695. North bank of Matanuska River at upper end of canyon at mouth of Eska Creek. G. C. Martin, 1910.

6696. Creek entering Granite Creek from west 5 miles above main trail, about half a mile west of and 470 feet above Granite Creek. G. C. Martin, 1910.

6689. Granite Creek, west bank, between altitudes of 1,000 and 1,050 feet. Position indicated in section on p. 320. G. C. Martin, 1910.

6705. Young Creek. Float. G. C. Martin, 1910.

6692. Pass between Kings River and Young Creek. G. C. Martin, 1910.

6699. 3,350-foot knob 1 mile north of east end of Chain Lakes. G. C. Martin, 1910.

6700. East bank of Kings River 0.35 mile above mouth. G. C. Martin, 1910.

6702. East bank of Kings River one-fourth of a mile above mouth. G. C. Martin, 1910.

6703. East bank of Kings River 3,850 feet below mouth of Young Creek. G. C. Martin, 1910.

6694. East bank of Kings River three-fourths of a mile below U. S. L. M. No. 1. G. C. Martin, 1910.

6691, 5893, 5894. East bank of Kings River at Coal Camp. G. C. Martin, 1910.

6701. North bank of Matanuska River 3½ miles above Kings River. G. C. Martin, 1910.

6704. Carbon Creek 3,875 feet above mouth. G. C. Martin, 1910.

8559. First tributary to Boulder Creek from the west above the canyon. Float. G. C. Martin, 1913.

8568. Float from same creek as No. 8559. R. M. Overbeck, 1913.

8560. About half a mile up first tributary to Boulder Creek from the west above the canyon. G. C. Martin, 1913.

8562. North slope of Anthracite Ridge near crest, at head of tributary to Boulder Creek next below East Fork. G. C. Martin, 1913.

8563. North slope of Anthracite Ridge at altitude 4,600 feet, at head of next to lowest tributary to East Fork of Boulder Creek. G. C. Martin, 1913.

8566. North slope of Anthracite Ridge near head of next to lowest tributary of East Fork of Boulder Creek. G. C. Martin, 1913.

3318. Crest of Anthracite Ridge near head of Purinton Creek. G. C. Martin, 1905.

3319. South slope of Anthracite Ridge near Purinton Creek, altitude 3,450 feet. G. C. Martin, 1905.

8577. North side of Boulder Creek at base of waterfall about 16½ miles above mouth. Shaly sandstone beneath conglomerate. G. C. Martin, 1913.

8596. South bank of Matanuska River 5 miles above mouth of Chickaloon River. G. C. Martin, 1913.

8595. North bank of Matanuska River 4 to 5 miles below O'Brien's Ford. G. C. Martin, 1913.

8592. North bank of Matanuska River 10 miles above Chickaloon River. G. C. Martin, 1913.

8593. About 1,000 feet up third tributary to Matanuska River from the north below O'Brien's Ford. R. M. Overbeck, 1913.

(48). Small gulch south of lowest tributary to Gravel Creek from the southwest, altitude 1,850 feet. R. M. Overbeck, 1913.

8594. Creek at east end of O'Brien Flats (lowermost large tributary of Gravel Creek), altitude 1,760 feet. J. B. Mertie, 1913.

8591. Hicks Creek opposite mouth of next to lowest tributary from the west. G. C. Martin and R. M. Overbeck, 1913.

8947. Knob 1 mile north of Matanuska River and 6½ miles northwest of Glacier Point. Theodore Chapin, 1914.

8948. Ridge between Hicks and Caribou creeks, 3½ miles north of Matanuska River. Theodore Chapin, 1914.

8586. Mouth of Alfred Creek. G. C. Martin, 1913.

8587. Alfred Creek 1,880 feet below main forks. R. M. Overbeck, 1913.

8590. Alfred Creek, exact position not known. Obtained from prospectors by G. C. Martin, 1913.

8578. Billy Creek about 4⅔ miles above mouth, altitude 3,800 feet. G. C. Martin, 1913.

CHITINA VALLEY

GENERAL FEATURES

The undoubted Cretaceous rocks of the Chitina Valley include the Lower Cretaceous Kennicott formation and an unnamed Upper Cretaceous formation composed mostly of shale that carries a marine Upper Cretaceous fauna.

The Lower Cretaceous Kennicott formation and beds which the writer believes should be correlated with it consist of sandstone and sandy shale, probably at least 1,000 feet thick, which are believed to lie unconformably on Upper Triassic rocks and to be overlain, probably unconformably, by Upper Cretaceous shale.

The Upper Cretaceous shale is about 7,000 or 8,000 feet thick. It is underlain with apparent conformity by conglomerate and sandstone that may be either basal Upper Cretaceous or Lower Cretaceous. It is apparently overlain by conglomeratic rocks that may be tentatively correlated with late Upper Cretaceous or basal Tertiary conglomeratic rocks on McCarthy Creek, which are overlain by volcanic rocks that are supposed to be Tertiary.

Near both the east and the west ends of the Chitina Valley are some conglomerate and sandstone of doubtful position. These beds rest unconformably upon the Upper Triassic formations and in the eastern part of the district are overlain with apparent conformity by Upper Cretaceous beds. They differ strikingly in lithologic character from any of the other Mesozoic formations of this region and also differ among themselves to such an extent that they either may or may not be regarded as a lithologic unit. They carry fossils which may be either Cretaceous or Jurassic, which may constitute one fauna or several faunas, and among which are none of the characteristic fossils of the recognized Cretaceous and Jurassic faunas of Alaska. The available evidence from the east end of the valley points strongly toward the Upper Cretaceous age of these rocks, and the doubtful rocks of that area will accordingly be described on pages 355–360 as probably Upper Cretaceous. In the western part of

the valley the evidence suggests that at least part of the doubtful sequence may be Lower Cretaceous, and the rocks of that area will therefore be described on pages 349–355 as possibly Lower Cretaceous, although Upper Cretaceous or even Jurassic rocks may perhaps also be present there.

The Upper Cretaceous shale of Chititu and Young Creeks is underlain, with apparent conformity, by sandstone and grit exposed on the tributaries of Dan Creek. The sandstone and grit rest unconformably upon Upper Triassic rocks and carry a very meager marine invertebrate fauna that might be either Cretaceous or Jurassic. The writer believes that the grit and sandstone probably form the basal member of a conformable Upper Cretaceous series.

The grit and sandstone of Dan Creek are probably the equivalent of the somewhat similar conglomerate, sandstone, and sandy shale of the headwaters of Nikolai Creek. These rocks also rest unconformably upon Upper Triassic rocks and grade upward into black shale that resembles the Upper Cretaceous shale. They likewise carry a sparse marine invertebrate fauna that may be either Cretaceous or Jurassic.

The shale here referred to the Upper Cretaceous has been described as being overlain by a massive conglomerate that crops out on the ridge south of Young Creek. It is doubtful whether the rocks really occur in this relationship, for not only are there indications of a fault at the base of the conglomerate, but the beds that appear to underlie the conglomerate are not known to be Upper Cretaceous. They differ in several important features from the known Upper Cretaceous rocks, are separated from them by a fault, and have not yielded any fossils. They are accordingly described on pages 369–371 as doubtfully Upper Cretaceous.

The Kotsina conglomerate and the overlying limestone and sandstone of the Kotsina and Kuskulana Valleys are also of doubtful position. These rocks have previously been referred to the Upper Jurassic, but this was done chiefly because of their apparent relationship to the supposed Upper Jurassic rocks of the Kennicott formation. The writer believes that the uppermost of these beds are certainly Cretaceous. The basal conglomeratic beds, which have yielded no fossils, might possibly be Jurassic, but the writer sees no reason for assuming that they are of different age from the somewhat similar basal Upper Cretaceous or the basal Lower Cretaceous conglomerates of the eastern part of the Chitina Valley.

The sequence and probable relations of the Cretaceous rocks in different parts of the Chitina Valley are indicated in the following table. In each of these areas except at the mouth of Chitina River the Lower Cretaceous rocks are underlain unconformably by Triassic rocks.

Probable relations of Cretaceous and Jurassic rocks in parts of Chitina Valley

Age	Mouth of Chitina River	Kotsina-Kuskulana district	Fohlin Creek and Kuskulana Pass	Headwaters of McCarthy Creek	Headwaters of Nikolai Creek	Dan, Chititu, and Young creeks	Upper Chitina Valley
Tertiary.			Coal-bearing shale and sandstone. Black shale.	Volcanic rocks. Conglomerate, sandstone, and shale, with some coal. Black shale.			
Upper Cretaceous.					Black shale.	Conglomeratic beds. Black and red shale.	
Lower Cretaceous.		Sandstone. Limestone. Kotsina conglomerate (may be Upper Cretaceous of may possibly be Jurassic).	Kennicott formation (greenish sandy shale and sandstone).	Sandy shale and conglomerate.	Sandstone and shale.	Yellowish sandstone.	Yellowish sandstone.
Upper Jurassic.							
Middle Jurassic.	Tuffaceous slate.						
Lower (?) Jurassic.	Tuffaceous conglomerate.						

LOWER CRETACEOUS

KENNICOTT FORMATION

Historical review.—The Kennicott formation was first described by Rohn[5] as the Kennicott "series" and was loosely defined as consisting of "light-colored arkoses, shales, and limestones." The type locality is at Kennicott Pass (now known as Fourth of July Pass), where the rocks constitute a very definite lithologic unit, containing *Aucella* and other fossils which were then considered Upper Jurassic. Rohn correlated these beds with an outlier near the head of McCarthy Creek, which consists of impure fossiliferous sandstone grading downward into a bed of conglomerate which rests unconformably upon the McCarthy shale. His map represents the Kennicott "series" as covering also a large area near the head of Kennicott Glacier. The description includes brief and general statements concerning the occurrence and character of these rocks and lists of fossils with a discussion of their age by T. W. Stanton.

The Kennicott formation was redefined by Schrader and Spencer[6] to include "a variable series of conglomerates, sandstones, limestones, and shales," which comprises (1) the original *Aucella*-bearing Kennicott formation of Kennicott Pass (minus a large area of Triassic rocks that were included in the Kennicott "series" on Rohn's generalized and necessarily inaccurate map); (2) an area of *Aucella*-bearing rocks in Kuskulana Pass that are doubtless identical with the original Kennicott formation; and (3) conglomerate and sandstone resting upon a surface of profound unconformity, occurring in many isolated mountain-top exposures on the watersheds of Kotsina River, Strelna Creek, Nikolai Creek, and Young Creek and carrying a fauna in which *Aucella* is strikingly absent. The rocks of this third division, in the writer's opinion, do not belong in the Kennicott formation, and part of them are probably not Lower Cretaceous. They are accordingly described elsewhere (pp. 349–358.)

The following description by Schrader and Spencer[7] applies to rocks that undoubtedly belong to the Kennicott formation:

To the east of Kuskulana Glacier it [the Kennicott formation] first appears in the bed of Trail Gulch, at an elevation of about 2,200 feet, and may be traced eastward for a distance of about 3 miles. In this locality the formation affords fossil remains. It does not appear again west of Lakina River, but to the east of that stream in the drainage of Fohlin Creek, it attains considerable development, having a thickness which possibly reaches 1,000 feet or

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[5] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 424, 428, 431–432, 433, 439–440, pl. 52, 1900.

[6] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special pub.), pp. 33, 48–50, pl. 4, 1901.

[7] Idem, p. 49.

more. In this locality and in the last it seems as if the formation was deposited in a submerged valley, the sides of which had considerable height above the level of the water.

This description contains also a list of fossils from all the supposed Kennicott localities. This is a combined list, which unfortunately is not representative of the fauna of this formation, for it includes the species from several localities that belong to Triassic and doubtful horizons. The statement to the effect that Stanton believed the fauna to correspond to that of the Knoxville formation is also not warranted.

In the reexamination of the mineral deposits of the Chitina Valley by Moffit and Maddren in 1907, the Kennicott formation, which does not contain ore deposits, was not studied in detail, and little new stratigraphic information concerning it was obtained. The account of the Kennicott formation by Moffit and Maddren[8] accordingly consists of a quotation of the full description by Schrader and Spencer.

The Kennicott formation was redefined by Moffit and Capps,[9] who extended its limits to include not only the sandstone and conglomerate of Nikolai Creek, which constituted part of the amended Kennicott formation as described by Schrader and Spencer, but also a large area and immense thickness of shale which had been mapped by Rohn as "unclassified sediments" and by Schrader and Spencer as "Triassic shales and limestones." Most of the rocks referred to the Kennicott formation by Moffit and Capps are now known to be Upper Cretaceous (see pp. 360–369), but the sandstone or arkose south of the Young Creek fault, in which no fossils have so far been found, is very different from the Upper Cretaceous shale north of the fault and is not unlike some of the Lower Cretaceous sandstone of the Kennicott formation exposed on Fohlin and Bear creeks. The writer believes that with this possible exception none of the rocks described by Moffit and Capps belong in the Kennicott formation as the term is here used, and it is doubtful (pp. 357, 359) whether any of them are Upper Jurassic or Lower Cretaceous. They were formerly referred to the Upper Jurassic because it was assumed that they were the same as the Kennicott formation of Fourth of July Pass and because this field determination was not disproved by the evidence from the small collections of fossils, which, as Stanton[10] said,

indicate that one fauna ranges throughout the formation and that its age is most probably Jurassic, though the types represented in the collection are

[8] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 30–32, 1909.

[9] Moffit F. H., and Capps, S. R., Gĕology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 31–43, 1911.

[10] Stanton, T. W., cited by Moffit, F. H., and Capps, S. R., idem, p. 39.

not as definite as could be wished for determining between Jurassic and Cretaceous. The entire absence of *Aucella* is noteworthy in view of the fact that that genus has previously been reported from the formation.

It should be pointed out that the collections upon which Stanton based the statement above quoted were very small and include no characteristic forms. The present assignment of these rocks to the Upper Cretaceous is not based upon a redetermination of these old collections but upon new collections that contain characteristic Upper Cretaceous genera.

In 1914 the writer made comparative studies of the rocks in Fourth of July Pass and on Chititu Creek. He recognized that the rocks at these two localities are not the same either lithologically or faunally. In Fourth of July Pass he obtained collections of marine fossils, including species of *Aucella* related to *Aucella pallasi* Keyserling, and collections of fossil plants which were obtained not only in the same beds but in the same pieces of rocks with the fossil shells. The marine shells and the plants were identified, by Stanton and by Knowlton, respectively, as Upper Jurassic. On Chititu Creek the writer obtained marine shells which Stanton identified as "certainly Upper Cretaceous."

The upper part of the Chitina Valley, including Chititu and Young creeks, was studied in 1915 by Moffit, who described the Mesozoic section as including sandstone that contains *Aucella* and other fossils which Stanton identified as "probably Upper Jurassic," together with fossil plants which Knowlton identified as Upper Jurassic, also another sandstone that contains ammonites and other marine shells, which Stanton assigned to "the basal part of the Upper Cretaceous or near the top of the Lower Cretaceous," together with fossil plants which Knowlton regarded as Upper Jurassic. These sandstones were not considered in the field as being of different ages and were differentiated in the description solely on the supposed evidence of the fossils.

The account of the supposed Upper Jurassic rocks of the upper Chitina Valley [11] includes a brief description of the character and distribution of the rocks and a discussion of their age and correlation, with lists of marine fossils as identified by Stanton. Lists of fossil plants from these localities, identified by Knowlton, are given elsewhere.[12] Moffit correlated the *Aucella*-bearing beds of the upper Chitina Valley with the Kennicott formation as restricted to the *Aucella*-bearing beds of Fourth of July Pass.

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[11] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 17, 18, 27–28, pl. 3, 1918.

[12] Idem, p. 44 (localities 7035 and 7037).

The account of the sandstone which Moffit recognized as Cretaceous[13] comprises a detailed description of the character and stratigraphic relations of the beds and a discussion of the age and correlation,[14] in which both the sandstone and the overlying Upper Cretaceous shale are included. Lists of fossils and discussions of their age by Stanton and by Knowlton are quoted. The lists include marine fossils from both the supposed Lower Cretaceous sandstone and from the overlying Upper Cretaceous shale, but the discussions by Stanton and Knowlton and the lists of plants apply only to the fossils from the sandstone. Stanton[15] states that the fauna includes many ammonites and other mollusks of Cretaceous types and that a reexamination of one of the older collections (8872) from the supposed Upper Jurassic rocks of the original Kennicott formation of Fourth of July Pass has revealed the presence of characteristic Cretaceous ammonoids.

The description of the supposed Upper Jurassic rocks of the Kotsina-Kuskulana district, by Moffit and Mertie,[16] contains a discussion of the character and age of the Kennicott formation.

Additional investigations of the area between Kuskulana River and Kennicott Glacier, including the type locality of the Kennicott formation, were made by Moffit[17] in 1916. The description of the Kennicott formation, based on the investigations in 1916 and other years, includes a discussion of the fossils by Reeside, who states that collections from the original Kennicott formation contain ammonites which are generally regarded as characteristic of the Cretaceous directly associated with *Aucella* and that the Aucellas from the Kennicott formation which had previously been compared with the Upper Jurassic species *Aucella pallasi* Keyserling belong to a different species from that in the Jurassic rocks of other Alaskan regions. Reeside suggests that the Aucellas of the Kennicott formation may belong to the Cretaceous subgenus *Aucellina.*

In 1922 Moffit studied the rocks on McCarthy Creek that Rohn included in the Kennicott formation, and obtained fossils which Reeside referred to Lower Cretaceous species of *Aucella.*[17]

Stratigraphic description.—The Kennicott formation, as restricted to the *Aucella*-bearing beds of Bear and Fohlin creeks and Kuskulana Pass, consists of greenish sandy shale and sandstone with numerous calcareous concretions and coarse grit that is partly conglomeratic. No stratigraphic section has been measured, and the thickness of the formation can be stated only approximately. The

[13] Moffit, F. H., op. cit., pp. 17, 18, 29–30.
[14] Idem, pp. 36–45.
[15] Idem, p. 41.
[16] Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 49–51, 1923.
[17] Moffit, F. H., Geology of the Chitina quadrangle (in preparation).

thickness is certainly several hundred feet and is probably 1,000 feet or more. Neither the basal nor the upper contact was observed, but on Fohlin Creek the Kennicott formation and the Triassic chert are exposed in close proximity and in such attitudes as to indicate that the contact at this locality is either an unconformity or a fault. The beds of the Kennicott formation have been involved in structural disturbances of the same general magnitude as those which have affected the Triassic rocks. They do not lie in slightly disturbed attitude across the eroded folds and faults of the older rocks, like the Upper Cretaceous (?) beds that were referred to the Kennicott formation by Schrader and Spencer and others. The statement by Schrader and Spencer[18] that at Trail Gulch and Fohlin Creek "it seems as if the formation was deposited in a submerged valley, the sides of which had considerable height above the level of the water," is a recognition of the marked difference in attitude between the *Aucella*-bearing beds of the original Kennicott formation and the Upper Cretaceous (?) sandstone and conglomerate which Schrader and Spencer regarded as part of the Kennicott formation and which were seen only as flat or gently folded hilltop cappings. The writer believes that the Kennicott formation rests unconformably upon the Triassic rocks and is beneath the great unconformity that has previously been regarded as basal Kennicott.

The sandstone of the upper Chitina Valley that Moffit assigned to the Upper Jurassic was described[19] as including soft brownish or pinkish sandstone and gray sandstone, both of which contain concretions, the largest 2 feet or more in diameter, some of them abundantly fossiliferous. The sandstone, of which about 500 feet is exposed, is of rather uniform character, so far as known, but contains two prominent thick beds, one at the base and the other near the middle, that are clearly distinguishable from the rest of the mass.

Moffit[20] stated that the discrimination of the supposed Jurassic and Cretaceous sandstones was based on the evidence afforded by the fossils and was not made in the field, for the sandstones are lithologically so much alike that no suspicion regarding a difference in their age was aroused. Both contain the same round concretionary masses and both, within a short distance of each other, rest unconformably on the Upper Triassic rocks.

A section of the supposed Cretaceous sandstone on Young Creek was described as including sandstone, possibly 100 or 200 feet thick, with massive basal beds grading upward into thin-bedded sandstone and sandy shale, above which are banded chert and hard platy-shale.

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[18] Schrader, F. C., and Spencer, A. C., op. cit., p. 49.

[19] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, p. 27, 1918.

[20] Idem, p. 30.

Possibly the sandstone and sandy shale replace each other along the bedding planes, but this is not probable. The thickness appears to be not less than 500 feet.

The Lower Cretaceous rocks on McCarthy Creek were described by Moffit[21] as follows:

> The base of the Cretaceous shale appears to be a yellowish-weathering bed, about 100 feet thick, in some places argillaceous and in some places sandy, which is exposed best on the east side of the valley. A massive bed of conglomerate, possibly 500 feet thick, is exposed on the east side of McCarthy Creek within the Cretaceous shale area but does not appear west of the creek. Its relation to the shale is in doubt. The whole of the ridge west of McCarthy Creek is black shale, probably Cretaceous in larger part.

Age and correlation.—The Kennicott formation lies unconformably on Upper Triassic rocks and is believed to be overlain unconformably by Upper Cretaceous beds. It contains abundant fossils, including both plants and marine invertebrates. The evidence on the age of the formation, as yielded by the different kinds of fossils and by the collections from different localities and as interpreted by the several paleontologists who have studied the fossils, is somewhat conflicting. This evidence, which is discussed in detail on pages 343–349, indicates, in the writer's opinion, that the formation belongs high in the Lower Cretaceous.

The following table shows the occurrence of all the fossils now known from the Kennicott formation, including not only the fossils from the type area of the formation in Fourth of July Pass but also those from the *Aucella*-bearing beds of Kuskulana Pass, from the *Aucella*-bearing sandstone and "Cretaceous sandstone" of the upper Chitina Valley, and from the *Aucella*-bearing sandy shale near the headwaters of McCarthy Creek—all of which, in the writer's opinion, are of the same age as the Kennicott formation.

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[21] Unpublished statement.

Fossils from Kennicott formation [a]

	8939	8926	8927	2195	9950, 7279	9951	9952	9949	9954	9955	9957	9963	2201	3	6812, 8873	2191	4	8876	8875	9976	9977	9978	8872, 6811	5	8877	8878	8879, 6814	8880	9965	9966	9967	9967a	9969	9971, 7280	9972, 7281	9973	9975
Sagenopteris alaskensis? Fontaine															c												c										
Sagenopteris					c																																
Equisetites (fragment without teeth)															c																						
Zamites megaphyllus (Phillips) Seward															c																						
Taxites zamioides (Leckenby) Seward															c								c				c										
Elatides curvifolia (Dunker) Nathorst															c																						
Araucaria? (single scale)															c																						
Pagiophyllum peregrinum Schimper															c																						
Coniferous wood																							c														
Wood																																			c		
Stems																																		c			
Rhynchonella (coarse ribbed)					b																																
Leda															a																						
Grammatodon?																							a														
Cucullaea									b	b																											
Inoceramus cf. I. concentricus Parkinson																																					b
Inoceramus (large form)																															b						
Inoceramus	a	a																																			
Avicula																							a														
Aviculid pelecypod					b																																
Aucella "cf. A. pallasi Keyserling"?				a	b	b	b						a	a	a	a	a			b	b			a		a	a		b	b	b	b		b	b	b	b
Aucella			a															a																			
Trigonia															a																						
Pecten		a													a																						
Pecten (Syncyclonema?)									b	b	b																										
Pecten (Camptonectes)																													b	b							
Pecten (Camptonectes?)																																		b			
Pleuromya															a																						
Tancredia?										b																											
Isocardia									b																												
Venerid pelecypod																													b								
Turnus																							a														
Dentalium															a														b								
Natica										b																									b		
Cinulia?																																		b			
Gastropods															a								a														
Phylloceras						b									a																		b		b	b	
Desmoceras (Puzosia?)																																			b		
Holcodiscus (Spitidiscus?)																				b		b													b		
Holcodiscus?																																b		b			
Ptychoceras																							a												b		
Lytoceras (Tetragonites) timotheanum Mayor																				b																	

Lytoceras (Gaudryceras) sacya (Forbes)																																		b		
Lytoceras (Gaudryceras)																													b				b			
Lytoceras					b								a		a								a					a			b					
Lytoceras?										b																										
Oppelia (Neumayria)?												b																								
Oppelia?															a								a		a	a	a									
Perisphinctes?															a			a	a							a										
Idoceras?															a																					
Olcostephanus?																a																				
Hoplites?													a																							
Straight ammonoid																							a													
Ammonites																								a												
Belemnites (Belemnopsis)								b	b	b																										
Barnacle (Lepadidae)											b																									
Shark teeth										b																										

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside, jr.; c, identified by F. H. Knowlton; d, identified by Arthur Hollick.

Fossils from Kennicott formation [a]—Continued

	9984	11369	11370	8871	6	11389, 7574	9981	9982	9983	11371	2200	11372	11373	11374	11375	11376	11377	11378	11380	9	12	9483, 7035	9484	9489, 7037	9481, 7034	9485	9486, 7036	9487	9488	9492, 7038	9470	9477	9479	9480	9490	9491
Cladophlebis cf. C. moissenti Saporta																									c											
Cladophlebis																									c		c									
Dictyophyllum																														c						
Hausmannia cf. H. forschhammeri or H. dichomata																														c						
Taeniopteris lindgreni Nathorst																									c											
Taeniopteris parvula? Heer																								c	c											
Sagenopteris phillipsi (Lindley and Hutton)																									c					c						
Sagenopteris																							c													
Sagenopteris?																									c											
Cycadites						d																														
Otozamites beani (Lindley and Hutton) Seward																									c											
Otozamites bunburyanus Zigno																									c											
Podozamites or Zamites																														c						
Ginkgo schmidtiana Heer																														c						
Elatides curvifolia (Dunker) Nathorst																						c			c											
Pinus nordenskiöldi Heer																														c						
Pagiophyllum peregrinum Schimper																														c						
Pagiophyllum																									c											
Stems																				c																
Serpula?																							a													
Rhynchonella																							a													
Rhynchonella?																				a																
Solemya?																														a						
Nucula																									a					a						
Nucula?																		b																		
Leda																												a		a						
Nemodon?																		b																		
Pinna																									a											
Inoceramus cf. I. concentricus Parkinson																									a		a	a		a	a	a				
Inoceramus sulcatus Parkinson																									a											
Inoceramus																									a								a			
Inoceramus?						b																														a
Aucella "cf. A. pallasi Keyserling"?	b				a		b	b	b	b	a			b										a												
Aucella cf. A. piochii Gabb												b	b				b																			
Aucella cf. A. crassicollis Keyserling															b																					
Aucella		b	b	a														b	b	a																
Aucella?																							a													
Trigonia																										a				a						
Pecten																														a						
Pecten (smooth)						b																														
Pecten (Camptonectes)																													a							
Pecten (Camptonectes?)									b																											

Thracia aff. T. semiplanata Whiteaves																		b																		
Thracia																												a								
Thracia?																						a														
Astarte?																					a						a	a		a						
Tancredia?																							a													
Protocardia?																						a														
Venerid pelecypod								b																						a						
Corbula																														a						
Dentalium																												a		a						
Dentalium?																								a												
Turbo?																												a								
Natica?																								a												
Amauropsis tenuistriata Whiteaves?																									a		a			a						
Anchura or Aporrhais																														a						
Tessarolax?																											a									
Actaeon?																														a						
Cinulia?																														a						
Cylichna?																										a										
Trichotropis? cf. T. konincki (Müller)																												a								
Gastropods																										a										
Phylloceras cf. P. ramosum Meek																									a					a						
Phylloceras																									a			a		a						
Desmoceras breweri (Gabb)						b																								a						
Desmoceras haydeni (Gabb)																												a		a						
Desmoceras (coarse ribbed)						b																														
Desmoceras																									a	a										
Desmoceras?																											a	a			a					
Desmoceras (Puzosia)																														a				a		
Holcodiscus cf. H. cumshewaensis Whiteaves																									a	a										
Holcodiscus																									a			a								
Baculites cf. B. teres Forbes																									a	a	a	a								
Lytoceras (Tetragonites) timotheanum Mayor																									a	a	a	a		a						
Lytoceras (Gaudryceras) sacya (Forbes)																									a			a		a						
Lytoceras																								a		a										
Perisphinctes?																								a												
Ammonites					a																	a								a					a	
Ammonite (aptychus?)																														a						
Belemnites																b																				

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside, jr.; c, identified by F. H. Knowlton; d, identified by Arthur Hollick.

8939. Ridge between Slatka and Trail Creeks, 1⅛ miles S. 39° E. from mouth of Slatka Creek, altitude 4,800 feet. F. H. Moffit, 1914.

8926. Southwest side of Trail Creek along trail, altitude 3,300 feet. Limestone. F. H. Moffit, 1914.

8927. Southwest side of Trail Creek along trail, altitude 3,500 feet. From soft shales. F. H. Moffit, 1914.

2195. Bed of stream near trail east of Kuskulana River, altitude 3,350 feet. A. C. Spencer, 1900.

9950, 7279 (F 32). Trail Creek, altitude 3,500 feet, on west side of creek. Soft gray sandy shale. F. H. Moffit, 1916.

9951 (F 33). Trail Creek, altitude 4,000 feet, small gulch on north side about 100 yards above forks of Trail Creek. Soft gray shale with concretions. F. H. Moffit, 1916.

9952 (F 34). On ridge about half a mile south of Kuskulana Pass. Float. F. H. Moffit, 1916.

9949 (F 31). Locality 41, on creek 1½ miles southwest of Trail Creek, tributary to Kuskulana River, 2,000 feet from creek, on southwest side, on point of ridge, altitude 3,900 feet, just below massive conglomerate. Black shale and limestone. F. H. Moffit, 1916.

9954 (F 36a). Northern tributary of Chokosna River, about half a mile above mouth of creek that flows from Kuskulana Pass, altitude about 4,200 feet. Conglomerate float near outcrop. F. H. Moffit, 1916.

9955 (F 37). Same creek as F 36a, altitude about 4,300 feet. Dark-gray sandy shale and sandstone. Belemnites of large size common. F. H. Moffit, 1916.

9957 (F 39). Chokosna River, on ridge east of F 37. Gray sandstone containing belemnites. F. H. Moffit, 1916.

9963 (F 45). Mill Creek, north side, half a mile from glacier on west fork. Float. F. H. Moffit, 1916.

2201. Old trail between Lachina and Kennicott Rivers. "Black shale series." A. C. Spencer, 1900.

(3). Boulder in creek between Lachina River and Fohlin Creek at camp 9. Oscar Rohn, 1899.

6812, 8873. East bank of Fohlin Creek, 4,900 feet above mouth of Bear Creek. Green sandstone with calcareous concretions. G. C. Martin, 1914.

2191. Creek tributary to Lachina River, half a mile above crossing of old trail between Lachina and Kennicott Rivers. "Black shale series." A. C. Spencer, 1900.

(4). East side of Fohlin Creek. Oscar Rohn, 1899.

8876. East bank of Fohlin Creek 5,500 feet above Bear Creek. G. C. Martin, 1914.

8875. East bank of Fohlin Creek 6,800 feet above Bear Creek. G. C. Martin, 1914.

9976 (F 59). Fohlin Creek at point 125 feet higher than mouth of Bear Creek. Gray and yellow sandstone and shale with nodular masses. F. H. Moffit, 1916.

9977 (F 60). Fohlin Creek 300 feet north of F 59. Yellowish sandstone overlain by gray shale near base of the Cretaceous rocks. F. H. Moffit, 1916.

9978 (F 61). Fohlin Creek 700 feet upstream from F 60. Yellowish-weathering sandstone. F. H. Moffit, 1916.

8872, 6811. Bear Creek about 2½ miles above its mouth. Float, the same piece of rock containing the plants of lot 6811. G. C. Martin, 1914.

(5). Three miles east of Fohlin Creek, between camps 11 and 12. Oscar Rohn, 1899.

8877. Bear Creek about 3 miles above its mouth. G. C. Martin, 1914.

8878. Bear Creek about 3 miles above its mouth, 100 yards above 8877. G. C. Martin, 1914.

8879, 6814. Bear Creek about 3 miles above its mouth, 100 yards above 8878. G. C. Martin, 1914.

8880. Bear Creek about 400 yards below summit of Fourth of July Pass. Calcareous concretions in gray sandy shale. G. C. Martin, 1914.

9965 (F 48). Bear Creek, tributary to Fohlin Creek. First northern tributary of Bear Creek, half a mile from mouth of Bear Creek. F. H. Moffit, 1916.

9966 (F 49). Same locality as 9965, but a short distance upstream. Contains a few plants. F. H. Moffit, 1916.

9967 (F 50). Same locality as F 47, but farther upstream, altitude about 2,900 feet. Sandstone abundantly fossiliferous. F. H. Moffit, 1916.

9967a. Loose block, probably from same locality as 9967. F. H. Moffit, 1916.

9969 (F 52). Falls of first northern tributary of Bear Creek, tributary to Fohlin Creek, altitude about 3,200 feet. In place. F. H. Moffit, 1916.

9971, 9980 (F 54). Boulder at same locality as 9969. F. H. Moffit, 1916.

9972, 7281 (F 55). Bear Creek, altitude 2,850 feet, about halfway from Fohlin Creek to Fourth of July Pass. Soft gray sandstone with nodular masses containing fossils. Base of the Cretaceous. F. H. Moffit, 1916.

9973 (F 56). Same locality as 9972. Plant remains. F. H. Moffit, 1916.

9975 (F 58). Tributary that joins Bear Creek 575 feet below Fourth of July Pass (farther west than F 57), several hundred feet from Bear Creek. Base of sandstone. F. H. Moffit, 1916.

9984 (F 67). Bear Creek. F. H. Moffit, 1916.

11369 (22F 6). Fall Creek, first tributary to Lakina River east of Fohlin Creek, 1,000 feet above mouth of Fohlin Creek. F. H. Moffit, 1922.

11370 (22F 7). Fall Creek, 1,200 feet above mouth of Fohlin Creek. F. H. Moffit, 1922.

8871. Upper end of canyon of Fourth of July Creek. Talus nearly in place. G. C. Martin, 1914.

(6). Canyon between camp 13 and Kennicott Glacier. Oscar Rohn, 1899.

11389, 7574 (22F 10). Northern tributary of Fourth of July Creek, 2 miles from Kennicott Glacier. F. H. Moffit, 1922.

9981 (F 64). First creek north of Fourth of July Creek, tributary to Kennicott Glacier, 275 feet above mouth of creek on north side. Gray shale, near base of Cretaceous. F. H. Moffit, 1916.

9982 (F 65). Near 64, but above it. Float. F. H. Moffit, 1916.

9983 (F 66). First creek north of Fourth of July Creek, tributary to Kennicott Glacier, 525 feet above mouth of creek. Base of the Cretaceous, yellow-weathering sandstone and gray shale. Nodules. F. H. Moffit, 1916.

11371 (22F 8). One-quarter mile up first creek north of Fourth of July Creek, tributary to Kennicott Glacier. F. H. Moffit, 1922.

2200. Along right edge of Kennicott Glacier, 7 miles above Pot Hole. Float. Schrader and Spencer, 1900.

11372 (22F 11). McCarthy Creek, half a mile below glacier. Float. F. H. Moffit, 1922.

11373 (22F 12b). McCarthy Creek, east side of west glacier, about halfway up glacier. F. H. Moffit, 1922.

11374 (22F 13). McCarthy Creek, first tributary below glacier on east side, near mouth. F. H. Moffit, 1922.

11375 (22F 14). McCarthy Creek, ledge on east side just north of second tributary below glacier. F. H. Moffit, 1922.

11376 (22F 15). McCarthy Creek, north side of second tributary on east side below the glacier, near mouth of stream. F. H. Moffit, 1922.

11377 (22F 16). McCarthy Creek, ridge south of second tributary on east side below the glacier, 2,200 feet above creek. F. H. Moffit, 1922.

11378 (22F 17). McCarthy Creek. Float. Boulder 2 miles below glacier. F. H. Moffit, 1922.

11380 (22F 19). McCarthy Creek. First tributary below glacier on east side. 200 yards up tributary. F. H. Moffit, 1922.

(9). Top of high mountain east of camp 20 on McCarthy Creek. Oscar Rohn, 1899.

(12). Near same place as No. 9. Oscar Rohn, 1899.

9483, 7035 (F 18). Top of ridge between Short River [Barnard] and Chitina glaciers, altitude 6,475 feet. Platy sandstone. F. H. Moffit and R. M. Overbeck, 1915.

9484 (F 19). Four miles northwest of lower end of Chitina Glacier, altitude 2,500 feet. Gray sandstone float from top of mountain on the north. F. H. Moffit and R. M. Overbeck, 1915.

9489 (F 31). South side of ridge between Young Creek and Chitina River, near trail, altitude 1,900 feet. Concretions in sandstone. F. H. Moffit and R. M. Overbeck, 1915.

7037 (F 31). Chitina Valley, at fork of stream near Chitina River-Young Creek trail; same locality as 9489. Sandstone nodules. F. H. Moffit and R. M. Overbeck, 1915.

9481, 7034 (F 15). North side of Chitina River, 1.4 miles N. 15° W. from Gibraltar. Round calcareous concretions in gray slaty sandstone. F. H. Moffit and R. M. Overbeck, 1915.

9485 (F 27). Creek 2 miles east of Canyon Creek, tributary to Chitina River, altitude 2,125 feet. Nodules in pinkish sandstone. F. H. Moffit and R. M. Overbeck, 1915.

9486 (F 28). Creek 2 miles east of Canyon Creek, tributary to Chitina River, altitude 2,150 feet. F. H. Moffit and R. M. Overbeck, 1915.

7036 (F 28). Chitina Valley, most easterly of three creeks entering lake together 2 miles east of Canyon Creek, altitude 2,150 feet; same locality as 9486. F. H. Moffit and R. M. Overbeck, 1915.

9487 (F 29). Mouth of Canyon Creek, altitude 1,460 feet. Nodules in gray sandy shale. F. H. Moffit and R. M. Overbeck, 1915.

9488 (F 30). Mouth of Canyon Creek, altitude 1,470 feet. Conglomerate at base of sandy beds. F. H. Moffit and R. M. Overbeck, 1915.

9492, 7038 (F 34). Bluffs of Young Creek, west of big bed. Concretions in sandstone. F. H. Moffit and R. M. Overbeck, 1915.

9470 (F 4). South side of Young Creek on ridge west of Young Creek-Chitina River trail, altitude about 5,100 feet. F. H. Moffit and R. M. Overbeck, 1915.

9477 (F 11). Young–Canyon Creek divide, altitude 5,600 feet. Black and gray shale. F. H. Moffit and R. M. Overbeck, 1915.

9479, 9480 (F 13). Head of east branch of Young Creek. Float. F. H. Moffit and R. M. Overbeck, 1915.

9490 (F 32). Southeast of bend of Young Creek, altitude 4,400 feet. Float in stream. F. H. Moffit and R. M. Overbeck, 1915.

9491 (F 33). Southeast of bend of Young Creek, in gulch, altitude 4,000 feet. F. H. Moffit and R. M. Overbeck, 1915.

The earlier collections of fossils from the original Kennicott formation of Fourth of July Pass and from the *Aucella*-bearing beds of Kuskulana Pass and McCarthy Creek, obtained by Rohn in 1899, by Spencer in 1900, and by the writer in 1914, were referred without question to the Upper Jurassic, both by Stanton for the marine invertebrates and by Knowlton for the plants. The marine fossils were considered Upper Jurassic because they include a species of *Aucella* related to *Aucella pallasi.* A reexamination of some of these fossils by Stanton revealed the presence of a Cretaceous ammonoid among them. The plants were considered Upper Jurassic because they include four species (*Elatides curvifolia*, *Pagiophyllum peregrinum*, *Zamites megaphyllus*, and *Taxites zamioides*) that occur in the supposed Jurassic rocks of Cape Lisburne, of Oregon, and of California, as well as in the Jurassic rocks of other parts of the world.

The flora of the Kennicott formation of the type locality comprises seven or more species of land plants. It should be noted that these fossil plants were not obtained from plant-bearing beds forming a distinct member of terrestrial origin but from beds of marine origin, all the plants occurring on the same rocks, as the marine shells and in immediate contact with them. Knowlton made the following statement concerning the plants collected by the writer in 1914:

> The number of forms present is not large, though it is perhaps larger than might ordinarily be expected in a marine deposit. The age indicated by these plants is undoubtedly Upper Jurassic.

The fauna at the type locality comprises marine mollusks, most of which belong to undetermined species and many of which are probably undescribed. It was formerly supposed to be closely related to the fauna of the Naknek formation of the Alaska Peninsula, the most characteristic species being a form of *Aucella* that Stanton compared with *Aucella pallasi* Keyserling. It should be noted that the Kennicott fauna apparently does not contain the ammonite *Cardioceras*, which is characteristic of strata that have been included in the Naknek formation of Cook Inlet (pp. 175-176) and which has been found also in the Upper Jurassic rocks of the Matanuska Valley (pp. 231-232). *Cardioceras* is supposed to be characteristic of a lower horizon in the Upper Jurassic than that of *Aucella pallasi.* The absence of *Cardioceras* in the rocks of the Chitina Valley is a further indication that they are Lower Cretaceous instead of Upper Jurassic.

The fossils collected by Moffit in the upper Chitina Valley in 1915 include collections that contain a species of *Aucella* related to *Aucella pallasi* which Stanton regarded as Upper Jurassic and also contain

fossil plants which Knowlton regarded as Upper Jurassic. Moffit also obtained, from beds that he regarded as the same as those which yielded the Aucellas, other collections that contain ammonites, other marine fossils, and fossil plants. The ammonites and other marine fossils were identified as belonging to species that have been found only in the upper part of the Lower Cretaceous and the lower part of the Upper Cretaceous and as including several genera that are not known to occur below the Cretaceous. The fossil plants, most of which came from the same localities as the marine fossils, were regarded by Knowlton as Upper Jurassic, although some of the species range up into the Wealden. The fossil plants were regarded by Knowlton as indicating the identity of the flora with that of the Kennicott formation of Fourth of July Pass. The sandstones of the upper Chitina Valley that Moffit described as Upper Jurassic and Cretaceous have yielded fossil plants which Knowlton [22] discussed as follows:

This material consists of five lots, all the specimens being small and many of them mere scraps. Although this material is very fragmentary, most of it permits the easy recognition of generic types, but some of the species have been identified with difficulty and doubt. However, the material has been studied with great care and much literature has been consulted. The following specimens have been identified with reasonable certainty:

Elatides curvifolia.
Pagiophyllum peregrinum.
Pagiophyllum sp.?
Pinus nordenskiöldi.
Ginkgo schmidtiana.
Podozamites or Zamites sp.
Otozamites beani.
Otozamites bunburyanus.
Taeniopteris lindgreni.
Taeniopteris parvula? Heer.
Sagenopteris phillipsi.
Sagenopteris sp.?
Hausmannia cf. H. forschhammeri or dichotoma.
Dictyophyllum sp.
Cladophlebis cf. C. moissenti.
Cladophlebis sp.

The species first named (*Elatides curvifolia*), although first described (under the name of *Lycopodites curvifolius*) from the Wealden of Germany, has since been found abundantly in the Upper Jurassic of Spitzbergen. It is also found in the Upper Jurassic of Cape Lisburne. *Pagiophyllum peregrinum* is abundant in the English Jurassic and, so far as I recall, has not been found above this horizon. *Pinus nordenskiöldi* was described from the Upper Jurassic of Siberia by Heer and later was reported with some question from the Kootenai by Dawson. The *Ginkgo* is known only from the Upper Jurassic of the Amour. The *Podozamites* is of the type of *P. lanceolata* and may be one of the forms of that variable species, but as it has fewer

[22] Knowlton, F. H., cited by Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 42–44. 1918.

nerves than is usual it is not identified specifically and may be new. It also resembles small leaflets of *Zamites* such as *Z. megaphyllus*. *Taeniopteris lindgreni* is known only from the Upper Jurassic of Advent Bay, Spitzbergen. The other species of *Taeniopteris* is represented by a single fragment and is questionable. It is indistinguishable, so far as this fragment goes, from *T. parvula*, a well-known Upper Jurassic form. *Sagenopteris phillipsi* is a variable small species described from the Upper Jurassic of Yorkshire, England. The unnamed *Sagenopteris* may be one of the forms of the first-mentioned species, but as it is fragmentary it has not been positively identified. The *Otozamites* are mostly in the form of detached leaflets, in which, however, the nervation has been beautifully preserved. They may represent only one species, but as they differ very considerably in size they are referred to the two species distinguished by Seward, both of which are found in the Upper Jurassic of Yorkshire as well as in beds of similar age in France. The *Hausmannia* is represented by a single broken specimen which might with nearly equal propriety be identified with one of the forms of *H. forschhammeri* from the Lias or Rhaetic of Sweden or with *H. dichotoma* from the Wealden of Auddinburg, Germany, and elsewhere. The genus ranges through the Jurassic and Wealden but is not well authenticated in later Cretaceous beds. The *Dictyophyllum* is a mere fragment that can not be positively determined. It might well enough be *D. rugosum*, which is found in the Yorkshire beds. This genus is mainly confined to the Rhaetic and Lias but is represented in the Jurassic and Wealden, and a single species is known from the Kome of Greenland. The forms of *Cladophlebis* are more or less uncertain. They are represented by mere fragments of only a few pinnules with mostly obscure nervation and are very difficult to identify. One form may be compared with *C. moissenti*, from the French Jurassic, or with *C. heterophylla* as known from the Kootenai. They could also be compared with species from the Upper Jurassic and Wealden, but in truth the material is too scanty to permit a positive decision.

With the data available we now come to the point of deciding the probable age of these plants. It is obvious that most of the positively identified forms are found in the Upper Jurassic, and at least half of them have not been found in beds younger than this. Only two of the named species are known to range into beds as young as the Wealden or its approximate equivalent. As pointed out, however, the more or less fragmentary material by which several of the unnamed forms are represented might be assigned to either Upper Jurassic or Wealden species; but clearly, if they can not be positively identified as one or the other, they can not be allowed to weigh in the balance against those that can be and have been identified with reasonable certainty. I therefore express my conviction that these plant beds are Upper Jurassic in age, thus confirming the determination reached in the field.

According to a statement made by Moffit and accompanying the specimens: "These beds were referred to the Upper Jurassic on the basis of an assumption that only one known fossil flora occurs in the Chitina Valley and that these plants are the same as those that Martin and Overbeck obtained in 1914 from the Upper Jurassic *Aucella*-bearing beds on Fohlin Creek."

I believe this reasoning is correct, at least so far as it applies to the identity between the material here reported on and that from Fohlin Creek. There were only four positively named species in Martin's collections of 1914, and two of these are abundant and unmistakable in the present collections. I have reexamined the Fohlin Creek material in the light of the present collection and find that what I there called *Sagenopteris alaskensis?* is without much doubt the same as *Sagenopteris* sp.? in the Moffit material, and one specimen strongly

suggests *S. phillipsi.* I am now quite convinced that they are not the same as Fontaine's *S. alaskensis.* I also find in the Fohlin Creek lots what I failed to note before, namely, a single leaf that appears to be the same as what I am calling *Pinus nordenskiöldi* in this report; and I find, furthermore, that the *Zamites megaphyllus* of the Martin report (1914) is pretty close to, if not the same as, the *Podozamites* or *Zamites* sp. of the present report. This appears to me to afford strong presumption for the identity of the beds of Fohlin Creek and the present (1915) collections. The localities are separated by only 35 miles, I believe, and this is a short distance in Alaska.

I of course have no opinion as to the stratigraphic relations of the beds whence came the *Sagenopteris alaskensis* of Fontaine, my only contention being that the species is not the same as those that represent this genus in the collections from the Chitina Valley.

This flora has been carefully compared with the small flora, consisting of about fourteen forms, reported by Dawson and Penhallow from the Queen Charlotte Islands, and so far as can be made out the two have not a single form in common.

The marine fossils from the sandstones of the upper Chitina Valley that Moffit described as Cretaceous were discussed by Stanton[23] as follows:

These collections have proved of more than usual interest from the fact that they present positive evidence of a Cretaceous fauna, not previously recognized in Alaska, by means of which the beds containing it may be correlated with those at certain horizons in the Cretaceous of Queen Charlotte Islands, California, and India. * * * Lots 9481 (F 15), 9485 (F 27), 9486 (F 28), 9487 (F 29), and 9492 (F 34) contain enough distinctive ammonites and other diagnostic forms to leave no doubt that they are of Cretaceous age, and enough species are common to two or more of these lots to show that they all belong to a single fauna. The forms most important for correlation in these lists are the following:

Inoceramus sp. cf. I. concentricus Parkinson.
Inoceramus sulcatus Parkinson.
Amauropsis tenuistriata Whiteaves.
Baculites sp. cf. B. teres Forbes.
Lytoceras (Tetragonites) timotheanum (Mayor).
Lytoceras (Gaudryceras) sacya (Forbes).
Holcodiscus sp. cf. H. cumshewaensis Whiteaves.
Phylloceras cf. P. ramosum Meek.
Desmoceras haydeni (Gabb).
Desmoceras breweri (Gabb).

All these species except possibly the *Baculites* and the *Phylloceras* occur in the Haida formation, recently described by Mackenzie[24] as the lowest formation of the Queen Charlotte series, which series name is applied to all of the Cretaceous rocks of the Queen Charlotte Islands. Several of the species were in the collections which I identified for Mr. Mackenzie last year, and the others are listed and described in earlier reports by Whiteaves. The two species of *Lytoceras* and the two species of *Desmoceras* are also found in California, where they occur in the upper part of the Horsetown formation or the lowest part of the Chico. *Phylloceras ramosum* Meek also comes from the same part of the section in California. From these comparisons with the Cretaceous of Queen Charlotte Islands and of California I would assign the collections repre-

[23] Stanton, T. W., cited by Moffit, F. H., op. cit., pp. 37, 41–42.
[24] Canada Geol. Survey Summary Rept. for 1913, pp. 43–47, 1914.

sented by the list above given to the basal part of the Upper Cretaceous or to near the top of the Lower Cretaceous.

If the comparisons are carried to more distant regions the same general results are obtained. Thus the two species of *Inoceramus* listed are English species and are reported from the Gault and upper Greensand of England. They are also of types not known anywhere in older rocks than the Gault. *Baculites teres*, *Lytoceras timotheanum* and *L. sacya* occur in the Ootatoor group of India, which is assigned to the lower part of the Upper Cretaceous and contains many other species identical with or closely related to those of the Haida and upper Horsetown. Furthermore, these two *Lytoceras* species belong to the groups *Tetragonites* and *Gaudryceras*, respectively, by some treated as distinct genera, which are characteristically Cretaceous. *Baculites*, also, is unknown in pre-Cretaceous rocks. There is a possibility that the little form referred to *Baculites* in these collections may belong to *Ptychoceras*, another characteristic Cretaceous genus in which the long straight shell is bent back on itself. An example of *Ptychoceras* has lately been discovered (or rather uncovered) in one of Martin's collections of 1914 from Bear Creek (No. 8872). I am therefore changing the assignment of that lot from Upper Jurassic to Cretaceous. Some additional genera, such as *Anisoceras*, *Pachydiscus*, and *Thyasira*, found in the smaller lots of this collection, are not known from pre-Cretaceous rocks elsewhere.

As I see it, therefore, the invertebrate evidence is all strongly in favor of the Cretaceous age of the entire collection. The fauna of the best localities indicates a horizon slightly lower than that of the Cretaceous of the Matanuska Valley, but still far above the basal Cretaceous. There is no suggestion of an admixture of Jurassic types such as might be expected in the lowest Cretaceous, and my judgment is that the fauna is considerably younger than even the latest Knoxville. The fossil plants which, as Knowlton reports, belong to a Jurassic flora, are intimately associated in the same beds with the ammonites and other invertebrates which are referred to a Cretaceous fauna, the two localities (F 15 and F 34) which yielded the best collections of plants having also yielded the best collections of invertebrates. I think that the vertical range of the ammonites is better established than that of the plants.

The fossils collected by Moffit from the Kennicott formation of Fourth of July Pass in 1916 contain ammonites that Reeside regards as belonging to typical Cretaceous genera, together with the species of *Aucella* which Stanton had previously compared with *Aucella pallasi* but which Reeside regards as distinct from any of the Aucellas from other Alaskan Jurassic rocks and as probably belonging to the Cretaceous subgenus *Aucellina*. Among these fossils are several that indicate relationship with the fauna of the Lower Cretaceous sandstone of the upper Chitina Valley, though Reeside believes that the fauna of Fourth of July Pass may be somewhat older. The following statement was submitted by Reeside[25] concerning the fossils collected in 1916 by Moffit from the type area of the Kennicott formation:

Lot 9972 is of considerable interest in that it contains a species of *Aucella* usually compared with *A. pallasi* Keyserling associated with *Ptychoceras* sp.,

[25] Personal communication.

Lytoceras (*Gaudryceras*) sp., *Holcodiscus* (*Spitidiscus?*) sp., and what may be a species of *Desmoceras* (*Puzosia*). As *Aucella pallasi* is confined to the Upper Jurassic in Russia, California, and Mexico, and as the ammonites are all typically Cretaceous in other areas, some doubt arises as to the relationship of the Alaskan *Aucella* to *Aucella pallasi* or as to the true ranges of all the fossils in question. Lot 9976 contains *Aucella* and *Lytoceras* (*Tetragonites*) sp., and lot 9975 *Aucella* and *Inoceramus* sp. like *I. concentricus* Parkinson, of the Gault.

A comparison of the Aucellas in these collections of Moffit's with one lot collected in 1915 (9489) and with several extensive collections from the Kennicott formation by Martin and Overbeck in 1914 shows them to be the same—referable, I should say, to two species, an elongated form and an orbicular form. A further comparison with the other Alaskan Aucellas available indicated that they are all quite different. *Aucella* sp. like *Aucella pallasi* from the Matanuska country differs from the present forms in sculpture, though it is very like the published figures of the Russian *A. pallasi* in both form and sculpture. I find none of the published figures and descriptions to fit the form of the Kennicott Aucellas except those of the subgenus *Aucellina* Pompeckj, which is Cretaceous. Pompeckj, in discussing several species of this group, says that they are surprisingly like *Aucella pallasi*. One might even refer the more orbicular Kennicott Aucellas to the species *A.* (*Aucellina*) *gryphaeoides* Sowerby, as it is described and figured by several writers, though on neither this nor the elongate species is there enough of the shell preserved to show the diagnostic hinge of the left valve.

A reexamination of the ammonites with the Aucellas of Martin's collections shows complete agreement with those of Moffit by the presence of *Lytoceras* (*Gaudryceras*) and *Holcodiscus* (*Spitidiscus?*), and also, associated with the same species of *Holcodiscus* found with the Aucellas, a specimen of *Ptychoceras* (mentioned by Stanton in a previous report).

It seems to the writer much more likely that the Aucellas of the Kennicott are not really *A. pallasi* Keyserling, but are of other species (probably of the subgenus *Aucellina*) than that the ammonites associated with them range so much lower than is true in other areas.

The complete absence of a number of very diagnostic forms found in 1915 by Moffit and referred by Stanton to the Cretaceous—such as *Inoceramus sulcatus*, *Desmoceras haydeni*, *D. breweri*, *Anisoceras* cf. *A. armatum*, *Thyasira* sp. *Pachydiscus* sp., *Baculites* cf. *B. teres*, and *Holcodiscus* cf. *H. cumshewaensis*—points to a different, probably older horizon within the Cretaceous for lots 9966, 9967a, 9972, 9975, 9976, 9978. Whether the other lots containing *Aucella* like *A. pallasi* and lacking more diagnostic fossils belong with those just listed is a matter for the field geologist to determine, though the presumption is reasonable that all belong to the one Cretaceous fauna.

The sandy shale exposed along the upper part of McCarthy Creek yielded several lots of fossils, collected by Moffit in 1922, which Reeside has determined as Lower Cretaceous. The collections contain several species of *Aucella* including forms related to the characteristic Lower Cretaceous species *Aucella piochii* and *Aucella crassicollis*, as well as the common form occurring in the Kennicott formation which Stanton compared with *Aucella pallasi* but which Reeside suggests may be a species of *Aucellina*.

The writer believes that the Kennicott formation of Fourth of July Pass; the *Aucella*-bearing beds of Kuskulana Pass, McCarthy Creek, and the upper Chitina Valley; and the "Lower Cretaceous sandstone" of the upper Chitina Valley are approximately of the same age and should all be assigned to the Lower Cretaceous. The reasons for this age assignment are that several of the invertebrate genera are known only in the Cretaceous, whereas none of the genera of either invertebrates or plants are known only in the Jurassic; that the Cretaceous species of invertebrates outnumber the Jurassic species of plants; that almost half of the positively or approximately identified species of plants range up into the Cretaceous, whereas only one invertebrate species may possibly range down into the Jurassic; that only one of the supposed Jurassic species of plants (*Zamites megaphyllus*) has been found in any of the undoubted Jurassic floras of southern Alaska, with which this flora, if Jurassic, should have its closest affinity; and that the general aspect of the fauna is wholly unlike that of the Upper Jurassic faunas of other Alaskan regions. (See pp. 274–283.)

LOWER (?) CRETACEOUS

KOTSINA CONGLOMERATE AND OVERLYING STRATA

Historical review.—The Triassic rocks of the Kotsina and Kuskulana valleys are overlain unconformably by conglomerate, limestone, and sandstone. These rocks carry Mesozoic fossils, but their exact age is doubtful. They appear to correspond approximately in lithologic and faunal character, as well as in their stratigraphic relations, to the Cretaceous conglomerate and sandstone of Nikolai and Dan Creeks, described on pages 355–360. These rocks have previously been described, in the reports on the reconnaissance surveys of this district, under two headings as indicated below. This separation was, however, not based upon stratigraphic or lithologic differences but was merely a distinction between the known and the unknown.

These rocks were described by Rohn[26] in part as the Kotsina conglomerate and in part as "unclassified sediments." The Kotsina conglomerate was described as a massive bed of conglomerate that overlies folded and contorted shale and slate that in turn rest upon the Nikolai greenstone. According to Rohn "the rocks above the Kotsina conglomerate are thought to be the same as the Kuskulana shales," but they were mapped as "unclassified sediments" and are now known to include part of the rocks here described, as well as several other formations. Rohn made only occasional references to the part of the "unclassified sediments" which are now under consideration and did not describe them.

[26] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pp. 422, 431–432, 1900.

These rocks were described by Schrader and Spencer in part[27] as "undetermined rocks on Kotsina River" and in part[28] as the Kennicott formation. The former includes all of Rohn's Kotsina conglomerate, together with additional areas that he mapped as "undifferentiated sediments." The latter includes several areas of conglomerate, limestone, and sandstone that cap the hilltops and obviously rest unconformably upon the upturned edges of the Triassic beds. This separation apparently has no stratigraphic basis but is essentially a distinction between the known and the unknown, or between the areas in which the stratigraphic relations to the unconformably underlying Triassic beds are clear and the areas in which the conglomerate is exposed at lower levels, where the unconformable relation is not so obvious.

The "undetermined rocks on Kotsina River" were described by Schrader and Spencer[29] as

a series of rocks whose relations and age have not been determined. They are made up of sediments, including limestones, shales, and coarse conglomerates, with intercalated sheets or flows of basalt like the Nikolai greenstone. The pebbles of the conglomerate are composed of greenstone material.

According to Schrader's unpublished field notes, "there seems to be a marked unconformity between the conglomerate and the [Chitistone] limestone. The limestone is much older than the conglomerate," and has apparently furnished the limestone pebbles in the conglomerate."

The so-called Kennicott formation of this district was described by Schrader and Spencer[30] as occurring in isolated outliers capping many of the high peaks and ridges between Kuskulana River and Clear Creek and resting unconformably upon all the formations from the Nikolai greenstone to the Triassic shale and limestone inclusive. Its lithologic characteristics in these areas were not described specifically.

These rocks were mapped by Mendenhall[31] in part as an unnamed conglomerate and in part as the Kennicott formation. The latter was described[32] as a "series of massive conglomerate with interbedded shales, the total aggregate thickness here being about 1,600 feet." The unnamed conglomerate, which is the same as the "undetermined rocks on Kotsina River" of Schrader and Spencer, was not described.

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27 Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), p. 40, pl. 4, 1901.

28 Idem, p. 49.

29 Idem, p. 40, pl. 4.

30 Idem, p. 49.

31 Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pl. 4, 1905.

32 Idem, p. 52.

The account of these rocks by Moffit and Maddren[33] consists of quotations in full of the descriptions by Schrader and Spencer, together with a very brief additional statement[34] regarding the "undetermined rocks on Kotsina River." They also made many important corrections on the geologic map.

These rocks have been mapped and described in detail by Moffit and Mertie[35] who described them as "Upper Jurassic rocks" and mapped them as three formations—the Kotsina conglomerate, a supposedly younger unnamed formation consisting of "sandstone, conglomerate, and shale," and a still younger unnamed "light-colored limestone." The description comprises a detailed account of the character, distribution, structure, and thickness of the beds exposed at various places and a discussion of their age and correlation, with a table showing the occurrence of the fossils as identified by Stanton.

Stratigraphic description.—The Kotsina conglomerate was described by Moffit and Mertie[36] as follows:

Unconformably overlying the Kuskulana and other formations is the Kotsina conglomerate probably of Upper Jurassic age. It consists of waterworn pebbles and cobbles inclosed in a shaly or arkosic matrix. The component pebbles are plainly derived from the formations already mentioned and from the intrusive rocks in them. The conglomerate weathers readily, yielding a characteristic rugged topography. Measurements of its thickness are of doubtful accuracy, but in the mountains north of Elliott Creek the conglomerate probably is from 1,500 to 2,000 feet thick.

The belt of rock just mentioned is made up of massive black conglomerate, almost without lines of bedding, yet containing a little black shale. It is composed largely of waterworn pebbles and cobbles, most of which are plainly of local origin and are derived from the underlying formations. Pebbles of greenstone, limestone, the light-colored granodioritic intrusives, and quartz are most common. It was noticed repeatedly that in the vicinity of areas of the Chitistone limestone the limestone pebbles in the conglomerate increase greatly in number and form a large proportion of the rock. The same is doubtless true of other constituents of the conglomerate, but these are not so readily seen.

The pebbles are inclosed in a shaly or arkosic matrix which disintegrates rather easily and breaks down rapidly under the influence of weathering. In consequence the outcrops are rough, and the talus slopes consist largely of pebbles freed from their matrix. The conglomerate mountains are rugged, with precipitous cliffs and a ragged sky line. Their dark color and rough surface give them a forbidding aspect, and in fact many of the ridges are practically impassable.

The later Mesozoic rocks of the Kotsina-Kuskulana district, in addition to the Kotsina conglomerate, include several detached areas

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[33] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 23, 30, 31, pl. 2, 1909.

[34] Idem, p. 21.

[35] Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, pp. 20, 44–51, pl. 3, 1923.

[36] Idem, pp. 20–45.

of conglomerate, sandstone, and limestone that may be partly or wholly the lateral equivalent of beds in the Kotsina conglomerate or may be younger. These are the rocks which Moffit and Mertie mapped [37] as unnamed Upper Jurassic formations and which they described [38] as follows:

The Jurassic rocks of this district in addition to the Kotsina conglomerate comprise limestone, sandstone, sandy limestone and shale, and fine conglomerate or grit. These beds are not widely distributed in the district and have heretofore been considered part of the Kennicott formation (Upper Jurassic). At one place the higher beds appear to rest unconformably on fine sandstone or grit that is referred to the Jurassic. The beds are highly fossiliferous. They have a thickness of possibly 500 feet east of Kuskulana River and of 880 feet west of the river, but in general the thickness is much less, not exceeding 100 or 200 feet.

The exposures of later Mesozoic rocks on the mountain between Clear Creek (tributary to Kotsina River) and Kluvesna River include several hundred feet of fine conglomerate, grit, and sandstone, which lie unconformably on the Upper Triassic rocks. These beds, which may be the lateral equivalent of part of the Kotsina conglomerate, grade first to a grit made up of tiny flattened pebbles of fairly uniform size and then to a soft yellowish-brown fossiliferous sandstone. About 50 feet of massive light-gray limestone with a slightly sugary texture and surface peppered over with tiny black specks rests on the brown sandstone and is overlain in turn by a small thickness of gray limy sandstone. Both the limestone and the sandstone are fossiliferous.

The fossils of lots 8935 and 8924 were obtained near the base of the sandstone and grit, and lot 8934 (float) probably came from the same horizon. Lot 8936 was obtained near the top of this member, not far below the base of the overlying limestone. Lot 8937 was obtained near the base of the sandstone that overlies the limestone. It seems probable that lots 2210 and 2198 were also obtained from the upper sandstone member. Lot 8940 is float material of uncertain origin that probably came from some member of this section. The same is probably true also of lot 2196, which includes only a single specimen of *Inoceramus* that was formerly regarded by Stanton [39] as possibly identical with *Inoceramus eximius* Eichwald, a Middle Jurassic species from the Tuxedni sandstone of Cook Inlet. Stanton's later opinion [40] concerning this fossil is that—

It is probably not a Middle Jurassic species, because it is not identical with any of the species of that age in the recent large collections from Cook Inlet, and there is no other evidence of the presence here of the fauna that accompanies them.

[37] Op. cit., pl. 3.
[38] Idem, p. 20.
[39] Stanton, T. W., cited by Schrader, F. C., and Spencer, A. C., op. cit., p. 50.
[40] Personal communication.

The most satisfactory disposal of these rocks which can be made at present is to regard them as a somewhat unusual facies of the Kotsina conglomerate.

Sandstone and conglomerate occur in three small areas in the mountains west of Clear Creek in Kuskulana Valley. Approximately 800 feet of interbedded sandstone and conglomerate are exposed in the largest of these areas, near the head of Sheep Creek. The sandstone and conglomerate rest unconformably on Triassic shale and are faulted against the shale on the west. At the base is 200 feet of conglomerate, and above is sandstone with intercalated conglomerate beds. The fossils of lots 8155, 9933, and 2211 were obtained from these beds.

The exposures east of Kuskulana River occur in several small detached areas, some of which consist of grit or conglomerate and some of limestone. The exposures on Trail Creek occur within half a mile of the outcrops of the *Aucella*-bearing shale described on page 340, which is considered as belonging to the Kennicott formation. Their stratigraphic relation to the *Aucella*-bearing rocks is not definitely known, but the writer believes that they may belong to the Kennicott formation.

Age and correlation.—The Kotsina conglomerate has yielded no fossils, and there is no evidence on its age except that it rests unconformably on Upper Triassic rocks and is believed either to grade into or to be overlain by rocks that contain Jurassic or Cretaceous fossils.

The grit and overlying sandstone and limestone which are supposed to overlie or grade into the Kotsina conglomerate have yielded the fossils listed in the following table. These fossils may belong anywhere in the Jurassic or Cretaceous. They apparently contain no species that are characteristic of any definite horizons, but in its general character the assemblage is not unlike the fauna of the sandstone of Nikolai and Dan Creeks, which is believed to lie either at the base of the Lower Cretaceous rocks of the Kennicott formation or at the base of the Upper Cretaceous shale of Chititu and Young Creeks.

The writer believes that the Kotsina conglomerate may be tentatively referred to an indefinite position in the Cretaceous. It possibly represents a coarse phase of the Lower Cretaceous rocks, but it should not be included in the Kennicott formation. The overlying limestone is possibly the equivalent of the Lower Cretaceous Nelchina limestone of the Matanuska Valley (pp. 313–315) and of the Herendeen limestone of the Alaska Peninsula (pp. 292–295), although these correlations are improbable in view of the absence in the Kotsina of the characteristic Lower Cretaceous species *Aucella*

crassicollis Keyserling. The sandstone that caps the limestone and appears to overlap also upon other rocks is possibly the equivalent of the presumably basal Upper Cretaceous grit of Nikolai and Dan Creeks, described on pages 355–360. These assignments are, however, purely tentative and have very slight basis. The entire series may belong anywhere in the Cretaceous or may possibly be Jurassic. Stanton believes that the whole list in the following table is rather more suggestive of Jurassic than of Cretaceous.

Fossils from limestone and sandstone overlying the Kotsina conglomerate [a]

	8935	8934	8924	8936	8937	2210	2198	8940	2196	8168	8155	9933	9942	2211
Pentacrinus?													b	
Serpula				a										
Rhynchonella			a											
Terebratula			a											
Terebratula?			a											
Spiriferina?			a											
Nucula?				a										
Pinna? (young)				a	a									
Inoceramus sp. 1 [b]							a		a					
Inoceramus (large form)			a											
Inoceramus	a	a		a	a			a			a			a
Inoceramus?												b		
Pteria?												b		
Pecten			a	a	a									
Lima?													b	
Astarte?				a										
Lytoceras?	a													
Oppelia (Neumayria) or Hoplites													b	
Perisphinctes?				a	a									
Aspidoceras cf. A. cyclotus Steuer?													b	
Belemnites (large species)						a								
Belemnites				a				a		a	a			
Belemnites?												b		

[a] a, Identified by T. W. Stanton; b, identified by J. B. Reeside, jr.
[b] This is the species listed by Schrader and Spencer as *Inoceramus eximius*, but it is not the same as *Inoceramus eximius* Eichwald.

8935. Mountain north of mouth of Kluvesna River, about 1⅞ miles N. 47° W. from Ammann's cabin on Kluvesna River. Sandstone beneath a limestone bed. F. H. Moffit, 1914.

8934. Mountain north of mouth of Kluvesna River. Float from same locality as 8935. F. H. Moffit, 1914.

8924. Mountain north of mouth of Kluvesna River, about 2,000 feet S. 12° W. of 6,005-foot peak. Near base of grit. J. B. Mertie, 1914.

8936. Mountain north of mouth of Kluvesna River, about 9,950 feet N. 40½° W. from Ammann's cabin, on Kluvesna River, altitude 5,800 feet. Sandstone beneath a limestone bed. F. H. Moffit, 1914.

8937. Mountain north of mouth of Kluvesna River; same locality as 8936. Base of sandstone overlying the limestone bed. F. H. Moffit, 1914.

2210, 2198. On mountain 1½ to 2 miles north-northeast of camp 13c on Clear Creek. Sandstone. F. C. Schrader, 1900.

8940. Boulders in Limestone Creek near confluence with Clear Creek. G. C. Martin, 1914.

2196. Impure fossiliferous limestone 2¾ miles above the mouth of Clear Creek. "Large bouldery slab." F. C. Schrader, 1900.

8168. Divide between Nugget and Roaring Creeks. Theodore Chapin, 1912.

8155. First creek south of Clear Creek. Buff sandstone. Theodore Chapin, 1912.

9933 (F 15). Locality 13, on ridge between east branch of east fork of Strelna Creek and Clear Creek, at head of small creek between Squaw and Clear Creeks, altitude 5,500 feet. F. H. Moffit, 1916.

9942 (F 24). Locality 20a, saddle on ridge between Rock and Lime Creeks, 7,500 feet southeast of forks of Rock Creek, altitude 5,800 feet. Thin-bedded limestone 100 feet below saddle, on Rock Creek side. F. H. Moffet, 1916.

2211. North fork of Kuskulana River. F. C. Schrader and A. C. Spencer, 1900.

UPPER (?) CRETACEOUS

SANDSTONE AND CONGLOMERATE OF NIKOLAI CREEK

Historical review.—The Upper (?) Cretaceous sandstone and conglomerate that unconformably overlie the Triassic rocks at the head of Nikolai Creek were described and mapped by Schrader and Spencer [41] as part of the Kennicott formation, although they were not part of the Kennicott formation as originally described and probably do not belong in that formation. The part of this description which applies to the rocks in question consists of a very brief statement concerning their occurrence, character, and relations to the underlying Triassic beds.

These beds, as they are not known to contain valuable mineral deposits, were not studied in detail during the reexamination of the mineral deposits of the Chitina Valley by Moffit and Maddren, who accordingly described them merely by quoting the description by Schrader and Spencer in full without modification.[42]

A fossil leaf that was collected by A. C. Spencer in float material in the bed of Nikolai Creek and was probably derived from these beds was described and figured as *Sagenopteris alaskensis* n. sp. by Fontaine,[43] who considered that "its resemblance to *S. göppertiana* points to a Jurassic age, but a single fossil like this can not be decisive."

These beds were described in great detail by Moffit and Capps,[44] who regarded them as comprising the lower members of the Kennicott formation. Their account includes stratigraphic sections, detailed descriptions of the various beds, and lists of fossils as identified by T. W. Stanton.

Stratigraphic description.—The Upper (?) Cretaceous conglomerate and sandstone of Nikolai Creek are separated from the underlying Triassic rocks by a profound unconformity, which cuts across the beveled edges of the strongly folded subjacent strata. The beds above the unconformity are but gently tilted, and their basal con-

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[41] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), p. 49, pl. 4, 1901.

[42] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, p. 31, pl. 2, 1909.

[43] Fontaine, W. M., Plants from the Copper River region, Alaska: U. S. Geol. Survey Mon. 48, pp. 152–153, pl. 38, fig. 21, 1905.

[44] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 31–34, 36, 37, 39–40, pl. 3, 1911.

glomerate includes pebbles derived from all the underlying formations. These beds have the general sequence indicated in the accompanying section (fig. 8), and were described by Moffit and Capps[45] as follows:

The Kennicott formation where it is exposed about the head of Nikolai Creek may be subdivided into three members as follows: A basal member made up of conglomerate and sandstone; a second member consisting chiefly of light-gray, yellow-weathering shale; and an upper member of dark-gray or black shale interstratified with occasional beds of impure limestone or hard calcareous shale.

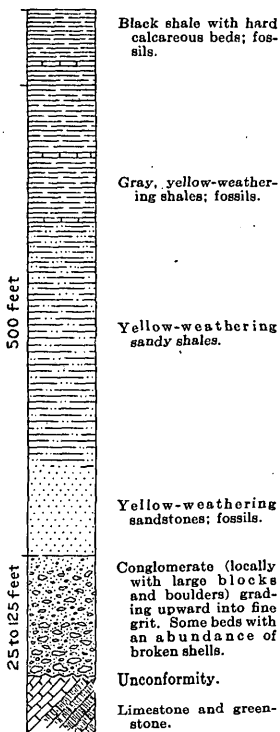

FIGURE 8.—Columnar section of the basal part of the Kennicott formation exposed on Nikolai Creek

The basal member * * * has a thickness ranging from 25 to 125 feet, the greater part of which is graywacke, the remainder conglomerate or grit. In a few places the basal member appears to be entirely absent, although because of faulting and talus slopes its seeming absence may be explained in other ways. Furthermore, its persistence as a whole in many other places in spite of rapid changes in character and of variation in thickness makes it probable that if it is not seen in a particular locality the failure to find it is due to one of the causes mentioned.

The middle member of the formation on Nikolai Creek shows far less variation in character than the lower one, but it does not appear so conspicuously in other parts of the Nizina region. It consists of shale and shaly sandstone, but shale predominates. The sandy phases are more or less local, and the best exposures are on the ridge south of Nikolai mine. A freshly broken surface of the shale shows a fine-grained rock of light color, but both shale and sandstone weather a bright yellow that makes them conspicuous wherever they are exposed. Both shale and sandstone break down into thin fragments under the influence of the weather, and the débris from their ledges gives rise to prominent talus slopes. Occasionally fossils are found in the sandstone, and rarely a shell is seen in the shale, but fossils are not abundant, and it requires some search to find any of value. The thickness of the yellow-weathering shales is as great as 500 feet in the mountain between Nikolai Creek and the East Fork of McCarthy Creek. At the head of Nikolai Creek 375 feet of yellow-weathering shale overlies the conglomerate, but some of the shale has been eroded away.

The highest member of the Kennicott in the Nikolai Creek vicinity consists of black shale, with interstratified hard, impure limestone and calcareous shale beds ranging in thickness from 1 inch to 2 feet. The hard beds form only a small proportion of the total thickness, probably less than one-tenth, but although jointed and broken they stand out in relief from the softer, crumbling black shales and form a conspicuous part of the whole. This black shale re-

[45] Moffit, F. H., and Capps, S. R., op. cit., pp. 31, 33.

sembles closely the black shales of the Triassic. The hard beds assume a rusty-yellowish color on weathering, just as in the Triassic shales, and there seems to be no way, except by their stratigraphic position and their fossils, to distinguish them from the older shales. Fossils are fairly plentiful in some beds of this member, especially those in the hard beds, and are in a better state of preservation than those found lower in the formation. From 125 to 150 feet of these shales are exposed north of Nikolai Creek, but the figures take no account of what has been removed by erosion or what has been caught up into the intruded porphyry.

Age and correlation.—These rocks bear a very close resemblance, both lithologically and in their relations to the underlying rocks, to the grit and sandstone of Dan Creek, described on pages 358–360. The fossils that have been obtained from these beds, which are listed in the table below, are not numerous or characteristic and consist of types that may be found in either the Cretaceous or the Jurassic, though they are however more strongly suggestive of the Cretaceous. They bear a general resemblance to the meager assemblage found in the grit and sandstone of Dan Creek. They include none of the species of the Kennicott formation, except possibly the plant, *Sagenopteris alaskensis* Fontaine, which was found in float material of uncertain derivation on Nikolai Creek and which has been only doubtfully identified (see p. 347) from the Kennicott formation. There is no reason to doubt that the conglomerate and sandstone of Nikolai Creek and the grit and sandstone of Dan Creek are equivalent. The latter probably (see p. 359) constitute the basal member of a conformable Upper Cretaceous sequence. The conglomerate and sandstone of Nikolai Creek consequently should also be regarded as probably Upper Cretaceous.

Fossils from Upper (?) Cretaceous sandstone of Nikolai Creek [a]

	6302	6307	6304	6305	6310	6313	8888	6308	6309	8892	8893	8894	6331	2193	2204	2208	11383
Sagenopteris alaskensis Fontaine															b		
Echinoderm or crinoid fragments															a		
Worm trails							a					a					
Rhynchonella			a	a	a				a				a	a	a		
Terebratella?				a	a								a				
Inoceramus	a							a	a	a	a					a	
Avicula															a		
Ostrea													a				
Exogyra				a													
Pecten			a	a											a		
Gastropods																	c
Phylloceras		a				a											
Lytoceras						a											

[a] a, Identified by T. W. Stanton; b, identified by W. M. Fontaine; c, identified by J. B. Reeside, jr.

6302. About one-seventh mile south of Nikolai mine. Calcareous sandstone overlying the basal conglomerate of beds formerly erroneously assigned to the Kennicott formation. F. H. Moffit, 1909.

6307. About five-eighths mile northeast of Nikolai mine. Talus near base of formation. F. H. Moffit, 1909.

6304. About half a mile N. 22° E. of Nikolai mine. Massive fine-grained grit overlying the basal conglomerate of the formation. F. H. Moffit, 1909.

6305. About one-fourth mile N. 25° W. of Nikolai mine. Arkose overlying the basal conglomerate of the formation. F. H. Moffit, 1909.

6310. About a mile N. 15° W. of Nikolai mine. Black sandstone and shale resting on greenstone. F. H. Moffit, 1909.

6313. Ridge between forks of McCarthy Creek, about 1¾ miles N. 30° E. of mouth of East Fork. F. H. Moffit, 1909.

8888. Three quarters of a mile N. 43° E. of Nikolai mine. Probably less than 100 feet above the base of the formation. G. C. Martin, 1914.

6308. Nikolai Creek, about five-sixths mile N. 18° E. of Nikolai mine. Sandstone and conglomerate. F. H. Moffit, 1909.

6309. Divide between headwaters of Nikolai Creek and East Fork of McCarthy Creek, three localities along ridge from 1 to 1⅓ miles north of Nikolai mine. Shale, sandstone, and conglomerate. F. H. Moffit, 1909.

8892. About 1¼ miles N. 48° E. of Nikolai mine. Float probably nearly in place and yellow calcareous sandstone 250 or 300 feet above base of formation. G. C. Martin, 1914.

8893. About 1¼ miles N. 52° E. of Nikolai mine, on crest of ridge. In place and probably from the same bed that yielded lot 8892. G. C. Martin, 1914.

8894. About 1 mile east of Nikolai mine, on top of mesa. Yellow sandstone float. G. C. Martin, 1914.

6331. South Fork of Nikolai Creek, about 1⅔ miles above mouth. Near base of formation. S. R. Capps, 1909.

2193. Arkose gravel from Nikolai Creek. F. C. Schrader and A. C. Spencer, 1900.

2204. Nikolai Creek. Boulder in stream near Nikolai City. F. C. Schrader and A. C. Spencer, 1900.

2208. Head of Nikolai Creek. F. C. Schrader and A. C. Spencer, 1900.

11383 (22 F 22). Ridge between forks of McCarthy Creek and East Fork at altitude 4,500 feet. F. H. Moffit, 1922.

GRIT AND SANDSTONE OF DAN CREEK

Historical review.—The Triassic rocks exposed on Dan Creek and its tributaries are overlain unconformably by fine conglomerate or grit and sandstone, above which, in apparently conformable sequence, is black shale that is seemingly continuous with and part of the Upper Cretaceous shale of Chititu Creek, which is described on page 362. These grit and sandstone beds were regarded by Moffit and Capps as the basal member of the Kennicott formation and as the equivalent of the sandstone and conglomerate of Nikolai Creek, described on pages 355–358. The account of these beds by Moffit and Capps [46] includes a detailed description of the exposures on the tributaries of Dan Creek, with lists of fossils as identified by T. W. Stanton.

Stratigraphic description.—The Upper Cretaceous (?) grit and sandstone of Dan Creek were described by Moffit and Capps [47] as follows:

[46] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 34, 40, pl. 3, 1911.

[47] Idem, p. 34.

An excellent exposure of the base of the Kennicott formation was found on Eagle Creek, in the Copper Creek valley. All the upper part of the long ridge separating Eagle Creek from Copper Creek is made up of lower Kennicott beds. They rest on the edges of thin limestone and shale beds that belong to the transition zone between Chitistone limestone and McCarthy shale. The limestone and shale beds have a dip about 20° greater than the overlying Kennicott, and the unconformity is shown in diagrammatic clearness. The basal beds of the Kennicott at this place consist of from 150 to 200 feet of fine conglomerate or grit overlain by sandstone. Black shale overlies the sandstone and forms the top of the ridge extending southeast to the main mountain mass. This basal grit was traced northwest in Copper Creek valley to the vicinity of the limestone area north of Idaho Gulch. It may be regarded as a constant feature of the Kennicott in the Nizina district. In most places it is somewhat fossiliferous.

Age and correlation.—The stratigraphic relations of these beds, which overlie the Triassic formations with a very great unconformity and which underlie the Upper Cretaceous shales with apparent conformity, indicate that their age may be either Jurassic or Cretaceous, but is more likely to be Cretaceous. The few fossils that have been found likewise indicate nothing more definite than this, for they all belong to genera that range throughout the Jurassic and Cretaceous.

These beds were referred by Moffit and Capps to the supposed Upper Jurassic Kennicott formation on the basis of a comparison, not with the original Kennicott formation, but with the conglomerate and sandstone of Nikolai Creek, described on pages 355–358. The age of the latter rocks is, however, subject to exactly the same doubt as that which attends the age of the rocks now under consideration. If these rocks are Lower Cretaceous they should contain some trace of the highly characteristic Kennicott fauna, which is so abundant in all the known outcrops of that formation. If they are Jurassic they should be separated from the overlying Upper Cretaceous shale by an unconformity. The writer believes that, in the absence of further evidence, they should be referred to the Upper Cretaceous and considered either the basal member of the Upper Cretaceous shale of Chititu Creek or a distinct formation in the same conformable series.

Fossils from Upper (?) Cretaceous rocks of Dan Creek [a]

	6316	6322	6334
Rhynchonella		×	
Inoceramus	×		
Undetermined small pelecypods		×	
Natica		×	
Phylloceras?			×
Undetermined ammonite		×	

[a] Identified by T. W. Stanton.

6316. South side of Dan Creek, 1⅗ miles east of mouth of Copper Creek. Talus. F. H. Moffit, 1909.

6322. Ridge between Copper and Eagle Creeks, about two-thirds of a mile east of the mouth of Eagle Creek. Near base of formation. F. H. Moffit, 1909.

6334. Ridge between Copper and Eagle Creeks, about 1 mile east of the mouth of Eagle Creek. Near base of formation. S. R. Capps, 1909.

UPPER CRETACEOUS

SHALE OF CHITITU AND YOUNG CREEKS

Historical review.—The Upper Cretaceous shale of Chititu Creek and vicinity has been described in several accounts of the geology of the Chitina Valley, but its Upper Cretaceous age was not recognized until 1914.

These rocks were mapped as "unclassified sediments" by Rohn,[48] who apparently did not study any of their exposures. They were included by Schrader and Spencer [49] in the "Triassic series" or "Triassic shales and limestones," but the Upper Cretaceous part of this aggregate was not recognized or described specifically. The account by Moffit and Maddren contains a description [50] of the "Triassic limestones and shales," which is quoted from Schrader and Spencer and consequently includes a description of the shale that is now known to be Upper Cretaceous. Brief mention of the Upper Cretaceous shale is also made in the description of the gold placers.[51] It is possible that the coal-bearing rocks near Fourth of July Pass and near the head of Chitistone River, described by Moffit and Maddren,[52] may also be Upper Cretaceous. The occurrence of the Upper Cretaceous rocks in the Chitistone Valley is suggested by a specimen of *Desmoceras* (lot 1696, p. 366) said to have been found in or near an area of coal-bearing rocks on the upper Chitistone. These rocks have never been examined by a geologist, although the occurrence of the coal has been briefly referred to by Mendenhall and Schrader,[53] by Mendenhall,[54] by Moffit and Maddren,[55] and by Moffit and Capps.[56]

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[48] Rohn, Oscar, A reconnaissance of the Chitina River and the Skolai Mountains, Alaska: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, pl. 52, 1900.

[49] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), pp. 33, 46–47, pl. 4, 1901.

[50] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 28–29, 1909.

[51] Idem, p. 93.

[52] Idem, pp. 32–33, 100.

[53] Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: U. S. Geol. Survey Prof. Paper 15, pp. 67–68, 1903.

[54] Mendenhall, W. C., Geology of the central Copper River region, Alaska: U. S. Geol. Survey Prof. Paper 41, pp. 124, 125, 1905.

[55] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pp. 32–33, 100, 1909.

[56] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, p. 73, 1911.

The detailed investigation of the geology of the Nizina district by Moffit and Capps established the fact that a great thickness of shale, lying south of the main fault of this district, regarded by the earlier observers as beneath the basal conglomerate of the Kennicott formation and previously mapped and described as part of the "Triassic shales and limestones," belonged in reality above the beds that had previously been considered part of the Kennicott formation. The limits of the Kennicott formation were accordingly extended[57] to include these beds. It is now known, however, that these strata are not Upper Jurassic and do not belong in the Kennicott formation. They constitute a distinct formation, which belongs above the Kennicott formation, and carries a characteristic Upper Cretaceous fauna. These Upper Cretaceous beds comprise the "interbedded sandstone and shale" and the "black shale with a few limestone beds" of the accompanying columnar section (fig. 9, p. 363), which is a modification of a section published in the report by Moffit and Capps[58] and which represents the Kennicott formation as mapped and described by them. The lower conglomerate and sandy beds of this section are the sandstone and conglomerate of Nikolai and Dan Creeks, which are described on pages 355–360 and which the writer believes are the basal beds of the local Upper Cretaceous sequence. The upper conglomerate of this section is the conglomerate of the ridge south of Young Creek, which is described on pages 369–371 and which the writer believes to be possibly the same as the conglomeratic beds of Nikolai and Dan Creeks.

The account of these Upper Cretaceous beds by Moffit and Capps[59] includes a detailed description of their occurrence, lithologic character, thickness, and stratigraphic relations. It includes also lists of fossils and a discussion of their age by T. W. Stanton.

In the description of the rocks of the upper Chitina Valley by Moffit, the Upper Cretaceous shale of Chititu Creek and vicinity is described as the "shales of Young Creek." This shale is considered as overlying with apparent conformity the Lower Cretaceous sandstone which the writer has correlated with the Kennicott formation (see pp. 334–335) and is apparently overlain, in the ridge south of Young Creek and some of the hills north of Young Creek, by conglomerate, arkose, and shale that are presumably Upper Cretaceous (see pp. 369–371). Moffit's account of the "shales of Young Creek"[60] includes a detailed description of their occurrence, lithologic character, and stratigraphic and structural relations.

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[57] Moffit, F. H., and Capps, S. R., op. cit., pp. 31–43, pl. 3.
[58] Idem, fig. 3, p. 37.
[59] Idem, pp. 31–43, pl. 3.
[60] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 17, 18, 29, 30–34, 44–45, pl. 3, 1918.

Lists of fossils as identified by T. W. Stanton are quoted,[61] but Stanton gave no general discussion of the fossils from the Upper Cretaceous shale, except in the following statement:[62]

The entire collection is believed to be Cretaceous, though a few of the smaller lots are uncertain because of the poor preservation or the great vertical range of the types represented.

A brief statement concerning the Upper Cretaceous age of this shale was made by Moffit and Mertie[63] in a discussion of the age and correlation of the later Mesozoic rocks of the Kotsina-Kuskulana district.

Stratigraphic description.—The Upper Cretaceous rocks of the Nizina district constitute a formation 7,000 or 8,000 feet thick, consisting chiefly of dark fissile shale. Much of the shale is sandy, and parts of the formation are made up of alternating shale and sandy beds. The shale contains numerous calcareous concretions. The general character of the formation is shown in the section (fig. 9).

The Upper Cretaceous shale of the Nizina district apparently includes all that portion of the rocks mapped as the Kennicott formation by Moffit and Capps[64] lying south of the fault that extends parallel to Copper Creek and to the east fork of Nikolai Creek and north of the fault on Young Creek, except the basal grit on Dan Creek that has been described on pages 358–360. The rocks south of Young Creek fault (pp. 369–371) are apparently different from those north of the fault and probably do not belong in the same formation. The exposures of shale in Sourdough Peak and on McCarthy Creek, at least as far north as Nikolai Creek, are probably Upper Cretaceous. The same formation apparently occupies some of the hills between Kennicott and Lakina rivers south of Fourth of July Pass.

These rocks rest with apparent conformity upon the grit and sandstone described on pages 358–360. At their contact with the sandstone ridge between Eagle and Copper Creeks, according to Moffit and Capps,[65] "black shale overlies the sandstone and forms the top of the ridge extending southeast into the main mountain mass." Their contact with the Lower Cretaceous sandstone at the bend of Young Creek is believed to be a fault.

The character of the rocks in the various parts of the formation is described in the following quotations from Moffit and Capps:[66]

Pyramid Peak, at the head of Copper Creek, appears to be made up entirely of rocks belonging to the Kennicott formation. The lower part is black shale,

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[61] Moffit, F. H., op. cit., pp. 37, 38, 40.

[62] Idem, p. 41.

[63] Moffit, F. H., and Mertie, J. B., jr., The Kotsina-Kuskulana district, Alaska: U. S. Geol. Survey Bull. 745, p. 50, 1923.

[64] Moffit, F. H., and Capps, S. R., op. cit., pl. 3.

[65] Idem, p. 34.

[66] Op. cit., pp. 34–35.

but the top shows bedding lines that are thought to represent sandstones and impure limestones. Sandy shales and hard sandstones are interstratified with the black shales on Rex Creek, and the tops of the mountains between Rex Creek and White Creek contain a large amount of gray sandstone and impure limestone. Beds of brown-weathering nodular limestone in the shales high

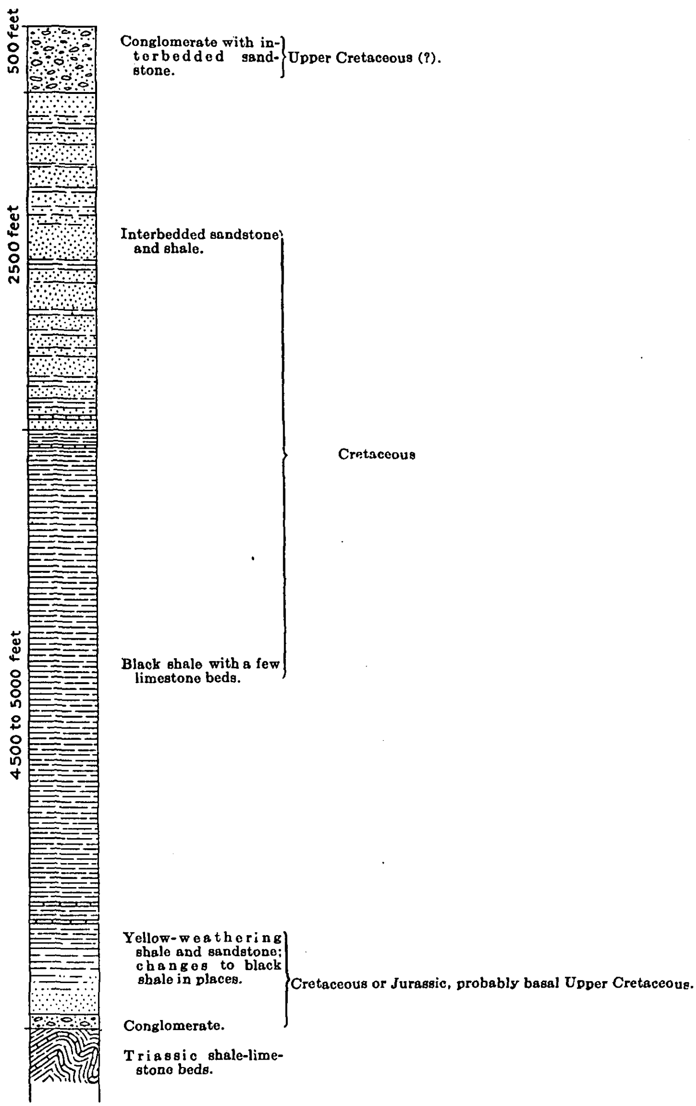

FIGURE 9.—Generalized columnar section of the post-Triassic sediments in the Nizina district. (After Moffit and Capps)

up on the slopes of these mountains contain ammonite shells 15 or 18 inches across. These mountains appear to be at the axis of a broad, shallow syncline and give good sections of the formations.

Bedding in the black shales of Blei Gulch, on the south side of Chititu Creek, is shown by lines of small limestone concretions and thin discontinuous calcareous beds. More than 4,500 feet of black shale dipping low to the

southwest is exposed in Blei Gulch. Young Creek, south of Chititu Creek, flows in a shallow canyon, whose walls are composed of black shale of the Kennicott formation. This shale forms the lower slopes of the ridge south of Young Creek, and it is probable that Kennicott sediments make up most of the ridge.[67] The ridge was not examined in detail owing to lack of time, but a section up the first southern tributary of Young Creek east of Calamity Gulch shows rocks of the Kennicott formation. The section extends up the east branch of this creek. For a distance of nearly three-fourths of a mile from its mouth the creek flows over black shales with occasional limestone beds, all dipping southwest at angles of 30° or less. Thence for nearly a fourth of a mile are rocks that have been crumpled and much faulted. They consist of shales with interbedded calcareous shales and limestone, from which fossils were collected. In many places the strata of this disturbed zone stand on edge, and it is evident that displacements of importance have taken place. A peculiar feature of this locality is seen in the limestone nodules, which occur in beds and reach diameters of 2 or 3 feet. They consist of bluish-gray limestone and show parallel bedding lines crossing them.

The following statement concerning the Upper Cretaceous shale on Young Creek was made by Moffit:[68]

The shales are prevailingly black and red or reddish brown but include some that are gray and greenish gray. They contain lime concretions and limestone beds, which are not distributed uniformly and which form only a small proportion of the total thickness of the sediments but which are highly conspicuous because of the contrast in color. Locally they contain also a relatively small amount of brownish-weathering sandy shale and sandstone. Dikes and sills of light-colored porphyritic rock and numerous thin "dikes" of sandstone cut them.

Nearly all the shale exposed in the canyon of Young Creek is black, except that toward the western end, which is red. It contains thin, widely separated brownish-weathering calcareous beds and limy concretions, which when seen in a large exposure give about the only evidence of structure that can be distinguished. The shale itself is broken into small fragments and commonly is without lines of bedding.

The thickness of the beds here referred to the Upper Cretaceous was discussed by Moffit and Capps,[69] as follows:

The black shale member at the heads of Copper and Rex creeks has a minimum thickness of not less than 4,500 feet, yet the black shales of Williams Peak, south of Dan Creek, suggest a considerably greater thickness, possibly as much as 6,000 feet. This measurement includes all beds from the top of the conglomerate and grit to the beginning of the interbedded shale-sandstone succession that forms the tops of the high mountains at the heads of Copper and Rex creeks and the upper part of the ridge south of Dan Creek. The shale-sandstone member has a thickness of about 2,500 feet.

Age and correlation.—The fauna of the Upper Cretaceous shale of the Nizina district, as represented in the following table, includes the marine invertebrates of 36 small collections from localities that are

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[67] For a later opinion concerning the identity of the rocks in this ridge see p. 370.

[68] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, p. 31, 1918.

[69] Moffit, F. H., and Capps, S. R., op. cit., pp. 37–38.

apparently distributed throughout the lower 4,500 or 5,000 feet of the beds exposed on Chititu and Young Creeks and their tributaries. The following statement concerning the fossils collected by the writer in 1914 was furnished by T. W. Stanton.[70]

The fossils from Chitina Valley include several lots from Blei Gulch that are certainly Upper Cretaceous and others probably of that age. The earlier collections from the same beds [collected by Moffit and others] contain nothing, so far as I can determine, that would prohibit their assignment to the Cretaceous. These collections are all small. The specimens of *Inoceramus* from sandstone northeast of the Nikolai mine may well belong to the same general fauna.

The lots that were determined as certainly Upper Cretaceous are Nos. 8857, 8860, 8865, and 8869. The other lots collected by the writer certainly came from the same formation as these. The earlier collections referred to above were obtained from the same or higher beds and may therefore be referred confidently to the Upper Cretaceous, too, although they had previously been determined by Stanton[71] as "probably Jurassic, though the types represented in the collection are not as definite as could be wished for determining between Jurassic and Cretaceous."

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70 Personal communication.

71 Stanton, T. W., cited by Moffit, F. H., and Capps, S. R., op. cit., p. 39.

Fossils from Upper Cretaceous shale of Chititu and Young creeks [a]

	4811	8868	6336	6324	6325	8859	8858	8857	8860	8861	8862	8863	8864	8865	8866	8867	8870	8869	6329	6326	6327	6328	6315	6301	1696	9467	9468	9469	9471	9472	9473	9474	9475	9476	9478	9493
Irregular echinoid				a																																
Echinoid							b																													
Serpula					a																				a											
Serpula?																																	a			
Rhynchonella?								b																												
Terebratula				a																																
Solemya																										a										
Nucula				a																																
Leda																		b																		
Nemodon n. sp								b																												
Nemodon?													b																							
Arca				a	a																															
Inoceramus n. sp										b																										
Inoceramus						b																														
Inoceramus (large thick-shelled species)																										a	a									
Inoceramus				a				a	b							b							a	a				a		a				a		a
Avicula																										a										
Ostrea				a	a			b			b			b	b						a					a										
Pecten				a	a																															
Anomia				a																									a	a	a					
Anomia?												b															a									
Cyprina occidentalis Whiteaves?																											a									
Cyprina?					a														a							a										
Lucina																												a								
Thyasira																																	a			
Isocardia?																										a					a					
Clisocolus?																										a										
Venerid pelecypod																															a					
Corbula					a			b																												
Teredo?											b																									
Pelecypods											b	b																a					a			
Dentalium								b						b																						
Dentalium?													b																							
Chemnitzia?					a																															
Aporrhais					a																															
Tessarolax								b																												
Tessarolax?															b																					
Gastropods				a				b		b								b								a										
Nautilus								b																												
Phylloceras n. sp														b																						
Phylloceras				a						a																										
Desmoceras n. sp											b																									
Desmoceras?															b			b							a											

Hauericeras?																																a			
Pachydiscus ramosum Meek var										b																									
Pachydiscus																																		a	
Pachydiscus?							b																												
Baculites cf. B. anceps Lamarck														b																					
Lytoceras		b								a	b																								
Perisphinctes?	a																																		
Anisoceras? cf. A. armatum Sowerby																															a				
Anisoceras?								b										b																a	
Crisoceras?					a																														
Ammonites			a													b	a			a		a													
Belemnites or Belemnitella													a																						
Undetermined decapod crustacean																		b																	
Crustacean claw																									a										
Shark teeth				a																															
Fish scales																		b																	

[a] a, Identified by T. W. Stanton; b, identified by W. R. Smith.

4811. Chititu Creek. Said to have been washed out from shale bedrock in hydraulicking on Kernan's claim No. 11. F. H. Moffit, 1907.

8868. Mouth of Rex Creek. S. R. Capps, 1914.

6336. Rex Creek. Shale in ground sluice on Kernan's claim No. 1. S. R. Capps. 1909.

6324. Small gulch tributary to Rex Creek, about 1⅓ miles N. 42° E. of mouth of Rex Creek, altitude 3,700 feet. Sandy shale. F. H. Moffit, 1909.

6325. Float at mouth of gulch 2 miles N. 33° E. of mouth of Rex Creek. F. H. Moffit, 1909.

8859. Blei Gulch, altitude 3,100 feet, on fork east of trail. G. C. Martin, 1914.

8858. Blei Gulch, altitude 3,200 feet, on fork east of trail. Concretions in soft gray shale. G. C. Martin, 1914.

8857. Blei Gulch, altitude 3,200 feet, on fork east of trail. Float from same locality as 8858 and probably from same beds. G. C. Martin, 1914.

8860. Float near mouth of Blei Gulch. G. C. Martin, 1914.

8861. Float near mouth of Blei Gulch. Another slab of rock from same place as 8860. G. C. Martin, 1914.

8862. Float near mouth of Blei Gulch. Another piece of rock from same locality as 8860. G. C. Martin, 1914.

8863. Float near mouth of Blei Gulch. Another piece of rock from same locality as 8860. G. C. Martin, 1914.

8864. Float from Blei Gulch. G. C. Martin, 1914.

8865. Float from mouth of Blei Gulch. Another piece of rock from same locality as 8860. G. C. Martin, 1914.

8866, 8867. Float from Blei Gulch. G. C. Martin, 1914.

8870. Float from White Creek. G. C. Martin, 1914.

8869. Trail on ridge south of bend of Virginia Creek, altitude 4,160 feet. Concretionary shale. G. C. Martin, 1914.

6329. East fork of tributary that enters Young Creek from the south half a mile above Calamity Gulch, altitude 3,450 feet. 15-foot limestone associated with shale. F. H. Moffit, 1909.

6326. West end of ridge between Rex and White Creeks, 2⅕ miles N. 62° E. of mouth of Rex Creek, altitude 5,700 feet. F. H. Moffit, 1909.

6327. Mountain at head of Grubstake Gulch, two-thirds of a mile S. 85° W. of 8,135-foot peak, altitude 6,250 feet. Black concretionary shale. F. H. Moffit, 1909.

6328. Mountain at head of Grubstake Gulch, one-fourth mile S. 55° W. of 8,135-foot peak, altitude 7,500 feet. Impure limestone that forms upper 500 feet of the mountain. F. H. Moffit, 1909.

6315. Sourdough Peak, about three-fifths mile S. 60° E. of summit, altitude 4,400 feet. Black shale. F. H. Moffit, 1909.

6301. McCarthy Creek, 2½ miles above mouth. Soft black shale. F. H. Moffit, 1909.

1696. "Chitina drainage near cannel coal." Received from Dan Kane by F. C. Schrader, 1902.

9467 (F1). Gulch on south side of Young Creek, three-fourths of a mile above mouth of Calamity Gulch. Nodular limestone in reddish shale. F. H. Moffit and R. M. Overbeck, 1915.

9468 (F2 and F2a). Creek on south side of Young Creek, about a mile above Calamity Gulch. Float in stream. F. H. Moffit and R. M. Overbeck, 1915.

9469 (F3). Near head of Sheep Creek, altitude about 5,200 feet. F. H. Moffit and R. M. Overbeck, 1915.

9471 (F5). West branch of Young Creek, 2 miles above forks, altitude 4,200 feet. Float. F. H. Moffit and R. M. Overbeck, 1915.

9472 (F6). West fork of Young Creek, about 2 miles above forks, opposite first glacier from west, altitude 4,300 feet. Nodular limestone. F. H. Moffit and R. M. Overbeck, 1915.

9473 (F7). West branch of Young Creek above first glacier from west, altitude 4,400 feet. Float. F. H. Moffit and R. M. Overbeck, 1915.

9474 (F8). Above F7 (9473), on west branch of Young Creek, altitude 4,500 feet. Float. F. H. Moffit and R. M. Overbeck, 1915.

9475 (F9). West branch of Young Creek, just below first glacier from the west, altitude 4,300 feet. Float. F. H. Moffit and R. M. Overbeck, 1915.

9476 (F10). East branch of Young Creek, on stream from the north, altitude 4,300 feet. Float. F. H. Moffit and R. M. Overbeck, 1915.

9478 (F12). Young-Canyon Creek divide, north of F11 (9477), altitude 5,750 feet. Black and gray shale. F. H. Moffit and R. M. Overbeck, 1915.

9493 (F35). Stream on south side of Young Creek, three-fourths of a mile above Calamity Gulch, altitude 3,225 feet. Concretions in black shale. F. H. Moffit and R. M. Overbeck, 1915.

UPPER CRETACEOUS (?)

CONGLOMERATE OF RIDGE SOUTH OF YOUNG CREEK

Historical review.—A conglomerate that occurs in several small areas on the crest of the ridge south of Young Creek was mapped by Schrader and Spencer[72] and also by Moffit and Maddren[73] as the Kennicott formation. These authors gave no specific description of this conglomerate.

The first published description of this conglomerate was given by Moffit and Capps,[74] who regarded it as the uppermost member of the Kennicott formation or as possibly representing "a succeeding formation." Their account includes a brief description of the occurrence and lithologic character of the conglomerate, with an estimate of its thickness, and a discussion of its probable stratigraphic position.

This conglomerate and the associated arkose and shale constitute the uppermost division of the Cretaceous rocks of the upper Chitina Valley as described by Moffit,[75] whose description includes a detailed account of the character, sequence, and stratigraphic relations of the beds. A statement by Stanton[76] concerning the single fossil which has been obtained from these beds is quoted.

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[72] Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), pl. 4, 1901.

[73] Moffit, F. H., and Maddren, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: U. S. Geol. Survey Bull. 374, pl. 2, 1909.

[74] Moffit, F. H., and Capps, S. R., Geology and mineral resources of the Nizina district, Alaska: U. S. Geol. Survey Bull. 448, pp. 35–36, 37, 38, pl. 3, 1911.

[75] Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 17, 18, 29, 34–36, 45, pl. 3, 1918.

[76] Idem, p. 41 (lot 9494).

Stratigraphic description.—The description by Moffit of the conglomeratic rocks of the ridge south of Young Creek contains the following statements:[77]

The beds consist of conglomerate, sandstone, sandy shale, and arkose; and, although the conglomerate is at first sight the most noticeable component of the whole mass, the sandstone, shale, and arkose predominate.

Section of Cretaceous conglomerate, arkose, and shale of Young Creek

	Feet
Sandstone, coarse, green and gray, interbedded with dark shales containing imperfect plant remains	700
Shale, brown and gray, with subordinate dark beds	700
Sandstone, greenish or greenish gray	100
Shale, fine grained, brown, gray, or greenish gray	700
Conglomerate and sandstone	300
	2, 500

Sandstone and shale, with subordinate conglomerate, correlated with the similar beds south of Young Creek, cap Pyramid Mountain and the highest peaks west of the upper part of Young Creek. They are particularly well seen in Pyramid Mountain, where they rest on black shale and appear to be horizontal, although they dip slightly to the southwest. Here also a thickness of about 2,500 feet is exposed, but the massive basal conglomerate was not observed.

In regard to the stratigraphic position of the sandstones of Pyramid Peak and the high mountains to the west there is no doubt. The nearly horizontal sandstone beds overlie the shale. The sandstone, shale, and conglomerate on top of the ridge south of Young Creek also overlie the shale, but in both places the exact nature of the contact is unknown. The contact south of Young Creek is, at least in places, a fault contact. In Pyramid Peak the sandstones have a slight southward dip, hardly enough to notice, but they show practically no folding. The underlying shales, on the other hand, are folded. This might seem to indicate depositional unconformity and folding of the shale before the sandstone was laid down; yet it should be remembered that the soft shales are much less able to withstand deforming pressure than the sandstone. In the places where the sandstone-shale contact was observed, on the west branch of Young Creek, the two formations appear to be conformable.

Age and correlation.—The only determinable fossil that has been found in the conglomeratic rocks south of Young Creek is a single specimen collected by Moffit in 1915 from sandstone within the area mapped as conglomerate. Stanton[78] has made the following statement concerning this fossil:

9494 (F. 36). Same stream as F 35 (9493), elevation 4,500 feet; from horizontal sandstone beds: *Inoceramus* sp., obscure imprint of a single specimen. Probably Cretaceous.

If the conglomerate south of Young Creek and the conglomeratic beds of Pyramid Peak are identical, as Moffit believes, there would

[77] Moffit, F. H., op. cit., pp. 35, 36.
[78] Stanton, T. W., cited by Moffit, F. H., op. cit., p. 41.

seem to be no doubt that they are Upper Cretaceous, for the conglomeratic beds of Pyramid Peak clearly overlie the Upper Cretaceous shale, whereas the conglomerate south of Young Creek appears to contain *Inoceramus* and therefore to be not post-Cretaceous. It is possible, however, that these rocks are not equivalent and that the conglomerate south of Young Creek, which is separated from the main mass of the Upper Cretaceous shale by a fault, may be directly underlain by the Lower Cretaceous sandstone of Young Creek or may even underlie the Lower Cretaceous sandstone. The conglomerate south of Young Creek may therefore belong either at the base of the Kennicott formation, or at the base of the Upper Cretaceous, or near the top of the Upper Cretaceous.

CONGLOMERATE AND OVERLYING VOLCANIC ROCKS OF M'CARTHY CREEK

Some late Cretaceous or post-Cretaceous rocks are exposed near the head of McCarthy Creek, concerning which Moffit[79] has submitted the following statement:

The high mountain at the head of McCarthy Creek and the crest of the ridges on both sides of the creek near this mountain are made up of horizontally bedded rocks, including sandstone, volcanic rocks, and conglomerate. Rhyolitic beds and tuffs are present. On the ridge west of the glacier the following section was seen:

Section near head of McCarthy Creek

	Feet
Cliff-forming volcanic rocks, sandstone, conglomerate, and shale.	
Black carbonaceous shale, intruded by dikes and sills of white sandstone. Contain some thin shaly coal near the top	350
Conglomerate and shale	50
Black shale at an altitude of about 5,000 feet. This is the thick shale of the Cretaceous.	

Some fossil plants that were collected at the base of the cliffs which form the upper member of the preceding section may have come from any of the beds therein. Arthur Hollick[79] has submitted the following statement concerning these fossils:

7575 (22 F 12 a). East side of west McCarthy glacier, about halfway up glacier, collected by F. H. Moffit, 1922. Nine pieces of matrix, consisting of fine-grained hard black shaly sandstone, containing an abundance of plant remains, mostly fragmentary, among which the following species were provisionally identified: *Equisetum perlaevigatum* Cockerell (=*E. laevigatum* Lesquereux)?; *Juglans rhamnoides* Lesquereux (=*Rhamnus rossmaessleri* Unger, fide Lesquereux)? Neither of these species, however, can be safely taken as an index fossil. Age, extreme Upper Cretaceous or lower Tertiary.

[79] Personal communication.

The volcanic rocks in the upper part of the section are probably Tertiary. The fossil plants, which may have been derived either from these beds or from some of the underlying strata, indicate a position either in the uppermost Cretaceous or in the Tertiary, one of the species occurring in the Laramie and the other in the Livingston. The strata beneath the volcanic rocks may perhaps be the equivalent of the conglomerate that is supposed to lie above the shale of Chititu Creek. The occurrence of coaly strata in the lower part of the section suggests that this may be the horizon of the coal beds of Fourth of July Pass and Chitistone River. (See p. 360.)

NUTZOTIN MOUNTAINS

GENERAL FEATURES

Lower Cretaceous strata containing *Aucella crassicollis* Keyserling are present in the Nutzotin Mountains east of Chisana River. These Lower Cretaceous rocks have not yet been differentiated, either in the stratigraphic section or on the map, from the Upper Jurassic *Aucella*-bearing beds (see pp. 240–245) with which they are closely associated and which they apparently resemble in lithologic character, or from the great body of metamorphosed and complexly folded slate and graywacke of the Nutzotin Mountains. The latter rocks may be largely Cretaceous or Jurassic or may include Paleozoic beds. They may belong with the somewhat similar rocks of doubtful position in other districts described on pages 480–487.

The general sequence of strata in the Nutzotin Mountains east of Chisana was described by Capps[81] as follows:

Quaternary:
- Glacial deposits, gravels, volcanic ash, peat, and other unconsolidated materials.
- Glacial morainal deposits, with associated lava flows.

Tertiary:
- Conglomerates and unconsolidated gravels.
- Sandstones, shales, conglomerates, and tuffs, locally containing lignite.

Cretaceous:
- Shales, slates, and graywackes.

Jurassic:
- Shales, slates, graywackes, and conglomerates.

Triassic:
- Thin-bedded limestone of Cooper Pass. Possibly includes also part of the slates and graywackes of the Nutzotin Mountains.

[81] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 29–30, 1916.

Carboniferous:
- Lava flows.
- Massive limestone.
- Lava flows and pyroclastic rocks.
- Massive limestones and shales.
- Basic lavas and pyroclastic beds, with minor amounts of sediments.

Devonian:
- Lavas and pyroclastic beds, with considerable black shale.

LOWER CRETACEOUS

AUCELLA-BEARING BEDS OF CHISANA AND WHITE RIVERS

Historical review.—The presence of Lower Cretaceous rocks in the Nutzotin Mountains was first indicated by Moffit and Knopf[82] on the basis of a small collection of fossils obtained by J. D. Irving at an unspecified locality "in the vicinity of Beaver Creek." No description of the rocks at this locality was given, and the published account consists merely of a statement, contributed by T. W. Stanton, concerning the character and probable age of the fossils.

Lower Cretaceous fossils were collected by S. R. Capps in 1914 from the shales on Chathenda Creek. The account of these rocks by Capps[83] includes only a general description, it not having been feasible, in the reconnaissance survey upon which this description was based, to differentiate the Lower Cretaceous *Aucella*-bearing beds from the Upper Jurassic *Aucella*-bearing beds or from the main body of the Jurassic or older slate and graywacke of the Nutzotin Mountains, with which the known Lower Cretaceous rocks are closely and complexly associated and to which they bear a strong lithologic resemblance. This account includes lists of fossils as identified by T. W. Stanton.

Stratigraphic description.—The Lower Cretaceous rocks of the Nutzotin Mountains consist of shale and graywacke that presumably overlie conformably the Upper Jurassic shale and graywacke described on pages 242–245. These Cretaceous and Jurassic rocks together were described by Capps[84] as follows, the reconnaissance character of his investigations and the structural complexity of the district making it necessary for him to regard them as an indivisible complex:

> The rocks that have yielded Jurassic and Cretaceous fossils on upper Bonanza Creek are dominantly shales and argillites, with much less interbedded graywacke than is present in the sediments which form the main mountain mass.

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[82] Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 29, 1910.

[83] Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, pp. 29, 47–53, pl. 2, 1916.

[84] Idem, pp. 50, 51, 52.

Some fine conglomerates are present, and a little impure limestone was seen, but the shales preponderate greatly. The proportion of graywacke is greatest in the lowest part of the section exposed and decreases upward.

The Cretaceous beds of this group lie immediately adjacent to the oldest known rocks of the region, the Devonian, and are separated from them by a profound fault.

Although the Mesozoic beds that have yielded Jurassic and Cretaceous fossils have been but slightly metamorphosed and are deformed only by a monoclinal tilting, the argillites, slates, and graywackes which form most of the Nutzotin Mountains and seem to lie structurally beneath the recognized Jurassic beds have been subjected to deformational stresses that have produced intricate folds.

The younger, fossiliferous slates of known Jurassic and Cretaceous age, as exposed on Bonanza and Chathenda creeks, are of less intricate structure, for they have rather uniform monoclinal dips to the southwest. They may also be reduplicated by faulting, but if the series is not reduplicated, the beds have a minimum thickness of 3,000 feet and may exceed that figure.

Structurally above the typical slates and graywackes of the Nutzotin Mountains, in the vicinity of Chisana placer mines, is a series of shales and graywackes, with some conglomerate, which has yielded fossils that are possibly of Upper Jurassic age. Its lower limit is not known, but its upper part merges, without any observed stratigraphic break, into rocks that are similar in lithology but bear Lower Cretaceous fossils.

Age and correlation.—The fauna of the Lower Cretaceous rocks of the Nutzotin Mountains, like those of all the other Lower Cretaceous rocks of Alaska, is characterized by one or more species of *Aucella*, other fossils being comparatively insignificant in numbers or in importance. The most numerous of these fossils is a species of *Aucella* that is closely related to if not identical with *Aucella crassicollis* Keyserling and that occurs in most of the other Lower Cretaceous areas of Alaska. The fossils from Beaver Creek are not well preserved but probably belong to this same species. The following statement concerning the Beaver Creek Collection was made by T. W. Stanton.[85]

> The specimens all belong apparently to a single species of *Aucella*, and though they are much compressed and considerably distorted they seem to be of the type of *Aucella crassicollis* Keyserling, which is referred to the Lower Cretaceous. The horizon is probably about the same as that of the *Aucella* bed from which Mr. Mendenhall collected on Matanuska River. Whether the fossils belong to the species mentioned or not they are certainly *Aucella*, and the age is therefore Lower Cretaceous or Upper Jurassic.

The *Aucella* in lot 8,811 apparently belongs to a different and older species which, according to Stanton,[86] is "probably Lower Cretaceous, and in my judgment from a somewhat lower horizon than Nos. 8,807 and 8,808."

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[85] Stanton, T. W., cited by Moffit, F. H., and Knopf, Adolph, Mineral resources of the Nabesna-White River district, Alaska: U. S. Geol. Survey Bull. 417, p. 29, 1910.

[86] Stanton, T. W., cited by Capps, S. R., The Chisana-White River district, Alaska: U. S. Geol. Survey Bull. 630, p. 52, 1916.

Fossils from Lower Cretaceous shale of Chisana and White rivers [a]

	8811	8807	8808	8810	(J. D. I.)
Aucella crassicollis Keyserling		×	×	×	
Aucella crassicollis?					×
Aucella	×				
Aucella				×	
Belemnites			×		

[a] Identified by T. W. Stanton.

8811. Gold Run Creek near its mouth. Shale and graywacke. S. R. Capps, 1914.

8807. Chathenda (Johnson) Creek. Black shale of Nutzotin (?) series. S. R. Capps, 1914.

8808. Bonanza Creek, claim No. 9. Black shale. S. R. Capps, 1914.

8810. Southeast fork of Chathenda (Johnson) Creek, 1¼ miles above its mouth. Black shale. S. R. Capps, 1914.

(J. D. I.) Vicinity of Beaver Creek. J. D. Irving, 1907.

SOUTHEASTERN ALASKA

GENERAL SEQUENCE

The rocks in southeastern Alaska that are believed by the writer to be of Cretaceous age include the *Aucella*-bearing sandstone, shale, and conglomerate of Pybus Bay and other localities in the southern part of Admiralty Island; shale and calcareous sandstone at Hamilton Bay, on Kupreanof Island; slate and graywacke on the west coast of Etolin Island; the conglomerate, slate, and graywacke of Blank Inlet, on Gravina Island; and possibly some graywacke, slate, and conglomerate on Prince of Wales Island. These rocks are distinguished from the somewhat similar slaty rocks that have been described as Jurassic on pages 245–262 by containing the Cretaceous rather than the Jurassic type of *Aucella* (on Admiralty and Etolin islands), by containing no volcanic beds, by containing conglomerate with pebbles of granite that are believed to have been derived from the supposed Jurassic granitic intrusive rocks, and by having in some localities, as on Pybus Bay, a notably lesser degree of metamorphism than the Jurassic slate and a distribution and attitude that is not controlled by the well-marked northwesterly structural, intrusive, and outcrop lines which show in most of the older rocks. The writer believes that these rocks are of Lower Cretaceous age and that they were laid down unconformably upon the Upper Jurassic and older beds after those rocks were folded and metamorphosed and after the intrusive rocks of the Coast Range had been partly unroofed. No Upper Cretaceous rocks have been recognized in southeastern Alaska.

LOWER CRETACEOUS

AUCELLA-BEARING BEDS OF PYBUS BAY

Historical review.—The Lower Cretaceous rocks of Admiralty Island were first described by C. W. Wright[87] as "conglomerates, graywackes, and slates." Wright gave a brief description of the lithologic character of the rocks, a statement that they lie unconformably upon more highly metamorphosed "limestones and schists" of Carboniferous age, and a discussion, by T. W. Stanton, of fossils collected at Pybus Bay. Although the evidence of the age of the rocks and much if not all of the information given in the description were obtained from Pybus Bay, it is stated that these rocks are mainly developed along the shores and on the Islands of Seymour Canal, that their northern continuation is found on Point Young, that they are also present on Portland Island, northwest of Douglas Island, and that rocks of similar appearance, which may belong to the same series, are found at Yankee Cove. This correlation of the rocks near Pybus Bay with the rocks on Seymour Canal and at the other localities mentioned above has not been established. (See pp. 256–257.)

The Pybus Bay locality was also visited by Kindle,[88] who gave a brief description of the character of the Lower Cretaceous beds and of their relations to the underlying "Upper Carboniferous" (Permian) limestone.

Brief mention of the Lower Cretaceous rocks at Pybus Bay has also been made by F. E. and C. W. Wright,[89] who stated that some of the fossils were obtained from limestone and calcareous shale

Stratigraphic description.—The Lower Cretaceous rocks of Pybus Bay consist for the most part of shale and conglomerate, with possibly some limestone near the base. They rest unconformably on Permian and Upper Triassic limestones. The section on Pybus Bay, according to Kindle,[90] is as follows:

Section on west shore of east arm of Pybus Bay

	Feet
Black to dark-gray argillaceous slates	300
Covered interval	100
Massive or heavy-bedded gray limestone, conchoidal fracture	40
Unconformity.	
Limestone and chert (Permian)	1,530

[87] Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, pp. 143–144, pl. 33, 1906.

[88] Kindle, E. M., Notes on the Paleozoic faunas and stratigraphy of southeastern Alaska: Jour. Geology, vol. 15, p. 332, 1907.

[89] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 34, 37, 40, 58, 1908.

[90] Kindle, E. M., op. cit., p. 332.

Kindle states that other outcrops just outside the bay indicate a total thickness of not less than 900 feet for the black slates. The section on Pybus Bay, according to the Wrights,[91] includes shale, conglomerate, and black limestone, more than 500 feet thick, underlain by more than 200 feet of gray limestone.

The exposures on the point between the arms of Pybus Bay, according to the unpublished observations of the writer, consist of gray shale with calcareous concretions containing *Aucella* (lot 8851), underlain, along the east shore of the west arm of the bay, by similar gray shale with calcareous concretions in which no fossils were found, interstratified with thin beds of yellowish sandstone. A few carbonized sticks were seen and also some black flint concretions. Worm tracks (lot 8852) were seen in some of the lower beds. According to Kindle's field notes,

> the outcrops along the point between the east and west arms of Pybus Bay are of the same character and horizon as the black shale in the upper part of the section on page 376. Small folds and changing dip and strike between the two localities prevented determination of the thickness of beds. Not less than 400 feet is exposed along the point, consisting of hard black slate with an occasional black calcareous band and numerous 3 to 6 inch bands of graywacke (volcanic) of olive-gray color. One or two species of *Aucella* (lot 9–a) occur in considerable numbers in some of the strata.

Kindle's field notes state that on the east side of the east arm of Pybus Bay the Carboniferous limestone and chert beds are found farther south than on the west shore, apparently as the result of an abrupt bend of the strike to the south. The cherty limestone that is the uppermost bed beneath the unconformity in the section on page 376 is represented here by a belt of extremely coarse conglomerate made up largely of fragments of fossiliferous Carboniferous limestone. Resting unconformably on it is 45 feet or more of gray limestone with Mesozoic fossils (lot 10a). These Mesozoic limestone beds are followed by the black slate. Edwin Kirk obtained Upper Triassic fossils (pp. 91–92) at or near this locality.

The exposures at Point Pybus, according to the observations of the writer, consist of conglomerate interbedded with sandstone and shale. Ammonites and *Aucella* (lot 8854) were found in pebbly shale just east of Point Pybus. The conglomerate and pebbly shale near Point Pybus are overlain, farther east along the coast, by gray shale like that on the point between the arms of Pybus Bay. This shale yielded several small collections of fossils (lots 8853, 8855, and 8856).

According to Kindle's field notes, on the point 1½ miles north of Point Pybus about 900 feet of interbedded conglomerate and "green-

[91] Wright, F. E. and C. W., op. cit., p. 34.

stone" are exposed. These rocks apparently pass into the fine-grained black shale which crops out exclusively on the west and north sides of the small bay.

Age and correlation.—The shale and conglomerate of Pybus Bay and vicinity are referred to the Lower Cretaceous on the basis of the fossils listed in the following table. Stanton[92] has made the following statement concerning some of these collections:

The specimens of *Aucella* from Pybus Bay, Admiralty Island, are apparently referable to species that in California and adjacent States are characteristic of the Lower Cretaceous, *Aucella piochii* occurring in a lower zone than *Aucella crassicollis.* The Alaskan specimens probably also come from the Lower Cretaceous, although strict correlation is rendered somewhat hazardous by the fact that the genus *Aucella* with similar specific forms ranges down into the Upper Jurassic.

Lower Cretaceous fossils from Admiralty Island [a]

	8850	8851	8852	C. W. 152	7a	9a	3310	10095	10169	8853	8854	8855	8856	C. W. 149
Worm trails			×											
Inoceramus? or Trichites?							×							
Aucella crassicollis Keyserling	×											×		
Aucella crassicollis Keyserling?					×					×				
Aucella crassicollis Keyserling? var														×
Aucella piochii Gabb				×										
Aucella piochii Gabb?		×				×		×	×					
Aucella											×			
Aucella?													×	
Ostrea?							×							
Gryphaea							×							
Phylloceras											×			
Undetermined ammonite	×													

[a] Identified by T. W. Stanton.

8850 (25). Admiralty Island, point at north entrance to Herring Bay. Gray shale which appears to underlie the Triassic limestone of Nos. 22, 23, and 24, but which is probably separated from the Triassic limestone by a fault. G. C. Martin, 1914.

8851 (26). Admiralty Island, point between arms of Pybus Bay. G. C. Martin, 1914.

8852 (27). Admiralty Island, 1 mile north of point between arms of Pybus Bay (on east shore of west arm). G. C. Martin, 1914.

C. W. 152. West entrance to north arm of Pybus Bay. Shale. C. W. Wright, 1904.

7a, 9a. Pybus Bay. E. M. Kindle, 1905.

3310 (10a). Pybus Bay. "45 feet of limestone below 9a and unconformable on Carboniferous limestone." E. M. Kindle, 1905.

10095. East end of point separating arms of Pybus Bay. Edwin Kirk, 1917.

10169. Point between east and west arms of Pybus Bay. Edwin Kirk, 1918.

8853 (30). Admiralty Island, 1 mile northeast of Point Pybus. Gray shale that appears to overlie the conglomerate of Point Pybus. G. C. Martin, 1914.

[92] Stanton, T. W., cited by Wright, C. W., A reconnaissance of Admiralty Island: U. S. Geol. Survey Bull. 287, p. 144, 1906.

8854 (31). Admiralty Island, three-fourths mile northeast of Point Pybus, Conglomerate that appears to underlie shale that yielded lot 30. G. C. Martin, 1914.

8855 (32). Admiralty Island, point at west entrance to cove 2 miles northeast of Point Pybus. Concretion in same shale formation that yielded lot 30. G. C. Martin, 1914.

8856 (33). Admiralty Island, point at west entrance to cove 2 miles northeast of Point Pybus, about 800 feet southwest of lot 32. G. C. Martin, 1914.

C. W. 149. Square Point, 4 miles southwest of False Point Pybus. Slate inclusions in conglomerate bed. C. W. Wright, 1904.

AUCELLA-BEARING BEDS OF KUPREANOF ISLAND

The only known Lower Cretaceous rocks on Kupreanof Island are found on the north end of the peninsula between Hamilton Bay and Keku Strait. These rocks, according to the unpublished observations of A. F. Buddington, consist of about 1,000 feet of thin-bedded gray shale and sandstone, 1 inch to several inches thick, with intercalated layers of fine-grained limestone from 6 to 12 inches thick. The beds have a general northwest strike and dip 10°–20° S. A few thin beds of tuff are intercalated with the other strata. East of Point Hamilton the Cretaceous beds are intruded by a mass of Tertiary gabbro. South of Point Hamilton they are overlain by Tertiary sandstone carrying fossil plants. At Point Hamilton a slightly calcareous sandstone bed 1 foot thick is exposed and has yielded abundant weathered blocks on the tidal flats. It is moderately fossiliferous, but the shells are mostly in fragments and poorly preserved (11404 and 11935). Traces of carbonized plant remains are found.

Similar beds, predominantly shale, are found in the line of islets lying south of Hound Island and halfway between it and Kuiu Island. A sill of basalt forms the backbone of this string of islets.

On the west headland of the cove about 3 miles southwest of Hound Island more than 300 feet of thin-bedded sandstone and shale with a few limestone layers are exposed. Beds of sandstone as much as 2 feet thick occur in the basal portion. These beds apparently overlie the Upper Triassic volcanic rocks, but the contact is covered, and the beds are nonfossiliferous.

The following statements concerning some fossils collected by Buddington have been submitted by T. W. Stanton:

11404 (44 Bu.). Kupreanof Island, islet at Point Hamilton. Thin-bedded sandstone with calcareous layers. Fossils rare and good specimens found only in weathered beds. A. F. Buddington, 1922.

Aucella? sp.

Pteria? sp.

The few fossils in this lot are small and imperfect, and the generic identification is not positive in either case. The collection is believed to be from the *Aucella*-bearing beds of Upper Jurassic or Lower Cretaceous age.

11935 (No. 44). Same locality as 11404. A. F. Buddington, 1923:
Worm trails or burrows.
Rhynchonella? sp., fragment.
Aucella sp.
Upper Jurassic or Lower Cretaceous.

AUCELLA-BEARING BEDS OF ETOLIN ISLAND

Historical review.—The Lower Cretaceous rocks of Etolin Island were mapped by the Wrights[93] in part as "Upper Carboniferous greenstone lava flows interbedded with volcanic tuffs and black slate" and in part as undifferentiated Paleozoic rocks. They gave no description of any of the rocks, which are now known to be Lower Cretaceous. The age of these rocks was first determined by the writer, who collected Lower Cretaceous fossils from them in 1914. Additional collections have been made by Buddington,[94] who gave a brief account of the lithology, age, and stratigraphic relations of these rocks, which he described as "Upper Jurassic or Lower Cretaceous."

Stratigraphic description.—The Lower Cretaceous rocks of Etolin Island were described by Buddington[94] as follows:

Neither the top nor bottom of the next series of rocks [Upper Jurassic or Lower Cretaceous] is shown. The lower portion of the series is essentially a black argillaceous slate formation, very thin bedded, with layers and partings of graywacke. Thin intercalated layers of rusty-weathering limestone are common, and many of the beds contain conspicuous nodules of blue-black chert and of limestone. Rarely a thin bed of fine conglomerate is present. The upper portion of the series comprises graywacke with intercalated beds of slate; the graywacke is in part thick bedded and in part thin bedded like the slate. Fossils collected from this formation were identified by T. W. Stanton as *Aucella crassicollis* Keyserling? and an imprint of *Belemnites* sp. He further stated that the *Aucella* occurs in the form of distorted specimens of the type *crassicollis*, which indicates Lower Cretaceous age if the specific identification is correct, and that the formation is not older than Upper Jurassic. The rocks of this series are the least metamorphosed of all the Mesozoic formations of this district.

Age and correlation.—The Lower Cretaceous age of the slaty rocks on the west coast of Etolin Island is shown by the fossils obtained at the localities listed below. These fossils were identified by T. W. Stanton.

8840 (13). Etolin Island, near cabins on small harbor behind island east of Screen Islands. G. C. Martin, 1914.

11077 (G–12). Small islet two-fifths of a mile west of Johnson's Cove on west side of Etolin Island. A. F. Buddington, 1921.

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[93] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pls. 1, 3, 1908.

[94] Buddington, A. F., Mineral deposits of the Wrangell district: U. S. Geol. Survey Bull. 739, p. 54, 1922.

Aucella crassicollis Keyserling? was found at both localities, and *Belemnites* at 11077.

CONGLOMERATE, GRAYWACKE, AND SLATE OF GRAVINA ISLAND

Historical review.—The supposed Lower Cretaceous rocks of Gravina Island are part of the "Gravina series" as described by Brooks.[96] In the report on the Ketchikan district by the Wrights[97] these rocks are not described but are mapped as "undifferentiated Paleozoic rocks." These rocks were described by Smith[98] as part of the "Triassic rocks of the east coast of Gravina Island" and as "undifferentiated Paleozoic schists." They were described by Chapin[99] as "Upper Jurassic or Lower Cretaceous conglomerate, slate, and graywacke." Chapin's description contains an account of the distribution, character, stratigraphic relations, structure, origin, age, and correlation of the beds.

Stratigraphic description.—The character of the Lower Cretaceous conglomerate, graywacke, and slate of Gravina Island and their relations to the underlying Jurassic rocks are indicated in the stratigraphic section on page 247. The Cretaceous rocks of Gravina Island were described by Chapin[99] as follows:

A formation consisting essentially of interbedded conglomerate, graywacke, and black slate exposed along a wedge-shaped strip extending from Blank Inlet to the northeast coast of Gravina Island is determined on fossil evidence to be Upper Jurassic or Lower Cretaceous, and similar rocks just northwest of Ward Cove are correlated with this formation.

The conglomerate does not appear to be the basal member but occurs at intervals throughout the formation interbedded with the graywacke and slate. It is composed of rather fine grained pebbles with a few boulders as much as a foot in diameter. The matrix is essentially a graywacke but contains a considerable amount of igneous rock fragments. The pebbles and cobbles are mostly igneous and resemble the volcanic rocks of Gravina Island. Pebbles of dioritic rocks resembling the plutonic rocks of the Coast Range also occur. No members of this formation are known to be of igneous origin, although both matrix and cobbles of some of the conglomerates contain so great an amount of igneous material that they resemble agglomerates.

The conglomerate passes by increasing fineness and decrease of igneous material into typical-looking graywacke with angular slate fragments. Microscopic examination of the graywacke shows it to consist essentially of quartz and feldspar grains with angular fragments of slate and decomposed particles of dioritic rocks, hornblende, pyroxene, and epidote. Flakes of biotite may be secondary, but no marked schistosity has developed.

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[96] Brooks, A. H., Preliminary report on the Ketchikan mining district, Alaska: U. S. Geol. Survey Prof. Paper 1, pp. 25, 40, 45, pl. 2, 1902.

[97] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pls. 1, 2, 1918.

[98] Smith, P. S., Notes on the geology of Gravina Island, Alaska: U. S. Geol. Survey Prof. Paper 95, pp. 95, 102–104, fig. 35, 1915.

[99] Chapin, Theodore, The structure and stratigraphy of Gravina and Revillagigedo Islands, Alaska: U. S. Geol. Survey Prof. Paper 120, pp. 97–98, fig. 11, 1918.

The slates are very fissile black clay slates and are closely interbedded with the graywacke members. The slates have a marked cleavage.

These Upper Jurassic or Lower Cretaceous beds overlie the volcanic rocks of Gravina Island described above and regarded as Triassic or Jurassic, but in most places the relations are rather obscure. On the northeast shore of Bostwick Inlet near the entrance the slates and graywacke overlie the eroded surface of the volcanic rocks with marked unconformity. On the northeast shore of Gravina Island conglomerates and graywacke overlie the volcanic rocks without apparent angular unconformity. The conglomerate and graywacke of Ward Cove are noticeably unconformable upon the black phyllite that has been correlated with the Upper Triassic rocks.

The conglomerate, slate, and graywacke beds of Blank Inlet occupy the trough of an overturned syncline in which are also involved the volcanic rocks of Gravina Island, which actually overlie them on the east shore of Blank Inlet.

These Upper Jurassic or Lower Cretaceous conglomerates, graywackes, and slates are the products of normal deposition in a shallow sea. The constantly changing character of the deposits indicates corresponding changes of conditions during their deposition. The materials of the rocks were apparently derived in part from the volcanic rocks of Gravina Island near by and in part from the surrounding regions.

Age and correlation.—The paleontologic evidence on the age of the slate and graywacke of Blank Inlet rests on a single collection of fossils, concerning which Stanton[2] reports as follows:

9527 (15 ACh 99). Blank Inlet, 1½ miles north of Blank Point, Gravina Island. *Belemnites* sp. Jurassic or Lower Cretaceous.

These fossils are insufficient to show whether the beds are Cretaceous or Jurassic, but an indication that they are Cretaceous is to be found in the absence of volcanic beds and in the presence in the conglomerate of boulders that seem to have been derived from the presumably Jurassic plutonic rocks of the Coast Range and of reworked igneous material, part of which was probably derived, according to Chapin, from the older volcanic rocks of Gravina Island.

GRAYWACKE, SLATE, AND CONGLOMERATE OF PRINCE OF WALES ISLAND

Lower Cretaceous rocks may be present in the southern part of Prince of Wales Island, where, according to the Wrights,[3] there are Cretaceous? graywacke, slate, and conglomerate, having an aggregate thickness of perhaps about 2,000 feet, which rest conformably on the Upper Jurassic (?) lava, tuff, conglomerate, and graywacke described on page 254. These rocks were described in the report cited as follows, and a similar description was repeated by C. W. Wright[4] in a later publication.

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[2] Stanton, T. W., cited by Chapin, Theodore, op. cit., p. 98.

[3] Wright, F. E. and C. W., The Ketchikan and Wrangell mining districts, Alaska: U. S. Geol. Survey Bull. 347, pp. 34, 58, pl. 1, 1908.

[4] Wright, C. W., Geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska: U. S. Geol. Survey Prof. Paper 87, pp. 19–20, pl. 1, 1915.

The graywackes overlying the andesites are compact and indurated, but do not show a schistose development (see Bull. 347, Pl. VII, *B*) ; the numerous slate fragments prominent in the rocks of the " Sitka series " to the north are absent, and beds of slate are less common. Pebbles of granodiorite, quartz, andesite, and graywacke are plentiful in the conglomerates. These beds, as a whole, though tilted at steep angles and folded, have not suffered the intricate folding and metamorphism shown in the older rock beds including the " Sitka series." No fossil evidence was found in these beds, but from the above facts it is reasonable to suppose that they occupy a position in the stratigraphic column between Triassic and Upper Cretaceous.

UPPER YUKON REGION

GENERAL FEATURES

The Cretaceous rocks of the upper Yukon region are known only in the banks of the Yukon and its tributaries between Eagle and Woodchopper Creek. They include marine Lower Cretaceous rocks, chiefly slate and quartzite, and nonmarine plant-bearing Upper Cretaceous shale, sandstone, and conglomerate. The Lower Cretaceous rocks are believed to rest unconformably on Triassic and Paleozoic formations, are probably several thousand feet thick, and carry a marine invertebrate fauna, including *Aucella* cf. *A. crassicollis*, which indicates a general correlation with the Lower Cretaceous *Aucella*-bearing beds of southern Alaska. The Upper Cretaceous rocks rest unconformably on Carboniferous rocks, are at least several hundred feet thick, and carry a terrestrial flora that indicates a correlation with the Upper Cretaceous plant-bearing beds of the lower Yukon region and with the Dakota sandstone. The Upper Cretaceous rocks are believed to be overlain unconformably by Tertiary (Eocene) plant-bearing beds.

LOWER CRETACEOUS

SLATE AND QUARTZITE

Historical review.—The Lower Cretaceous rocks of the upper Yukon district were first mentioned by McConnell,[5] who gives a brief description of the shale, sandstone, and conglomerate seen by him along the Yukon for 35 miles below the mouth of the "Tatonduc." Special mention is made of conglomerate overlying the shale 8 miles above Charlie Village and of fossils identified as *Aucella mosquensis* var. *concentrica* collected from the beds below the conglomerate " some miles below the mouth of the Tatonduc." A description is also given of similar shale and conglomerate observed by Ogilvie overlying Paleozoic limestone on the Tatonduk.[6]

[5] McConnell, R. G., Report on an exploration in the Yukon and Mackenzie Basins, N. W. T.: Canada Geol. Survey Ann. Rept., new ser., vol. 4, pp. 21D, 137–138D, 1891.

[6] Idem, p. 138D.

These Lower Cretaceous rocks were included by Spurr[7] in the "Mission Creek series." His description of that "series" includes the rocks of several areas which are now known to belong in widely different parts of the geologic column. The rocks described under the heading "Napoleon and Chicken Creeks"[8] have been described and mapped by Prindle[9] as Tertiary clay, sandstone, lignite, shale, and conglomerate with fossil plants. The rocks described by Spurr under the heading "Below Fortymile Creek"[10] are believed to be chiefly if not wholly Paleozoic. The rocks described under the heading "Mission Creek and below,"[11] which ought to contain the type section of the "Mission Creek series," include Tertiary plant-bearing shale, sandstone, conglomerate, and lignite beds,[12] and some shale, sandstone, and conglomerate that are Devonian or possibly basal Carboniferous.[13] The rocks described under the heading "Kandik River and vicinity"[14] are believed to be wholly Lower Cretaceous and are described in greater detail below.

Brief mention of the "Mission Creek series," without specific description of the Lower Cretaceous, *Aucella*-bearing members, was made by Brooks.[15]

A brief description by Collier[16] was based on field investigations that have not been described in complete detail.

The Lower Cretaceous rocks exposed along the Yukon were mentioned briefly by Prindle.[17]

A more extensive description of these rocks based on additional field investigations was given by Brooks and Kindle.[18] The same statement has been quoted by Prindle.[19]

The eastern extension of these Lower Cretaceous rocks exposed along the international boundary was included by Cairnes in the

[7] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 1, pp. 175–184, 257–258, 1897.

[8] Idem, pp. 175–176.

[9] Prindle, L. M., The Forty-mile quadrangle, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 375, pp. 24, 25, 26, pl. 5, 1909.

[10] Spurr, J. E., op. cit., pp. 176–178.

[11] Idem, pp. 178–180.

[12] Prindle, L. M., op. cit., pp. 23–24, 25–26, pl. 5.

[13] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks on the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 277, 286–288, 1908.

[14] Spurr, J. E., op. cit., p. 180.

[15] Brooks, A. H., The coal resources of Alaska: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, table opp. p. 526, pp. 530. 556, 1902.

[16] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 15, 16–17, 28, 32, 1903.

[17] Prindle, L. M., The Yukon-Tanana region, Alaska—Description of the Circle quadrangle: U. S. Geol. Survey Bull. 295, pp. 16, 17, 1906.

[18] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 305–307, 1908.

[19] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pp. 31–32, 1913.

"Orange group." The original description[20] of the "Orange group" contains an account of the lithologic character of the rocks with a statement by Stanton concerning some fossils. A brief supplemental description based on field work in 1912 has also been given by Cairnes.[21]

A later description by Cairnes[22] states that the "Orange group" consists of an undifferentiated assemblage of rocks ranging from upper Carboniferous to Lower Cretaceous.

In the latest report by Cairnes on this district[23] the use of the name "Orange group" was discontinued, and the Cretaceous rocks formerly included in the group are described under the heading "Mesozoic beds." The account includes a statement of the areal distribution of the rocks, a general description of their lithologic character, and a discussion of age and correlation in which there are statements by Stanton concerning the fossils. Cairnes[24] states that "it seems quite possible that Jurassic or even Triassic members may also be included." However, as most of the fossils obtained from these "Mesozoic beds" are characteristic of the Lower Cretaceous, as the rocks described by Cairnes bear a close resemblance to the Lower Cretaceous rocks and do not resemble the Triassic rocks on the Yukon, and as Jurassic rocks are not known anywhere in this region and are believed never to have been deposited in the Yukon Basin, the present writer concludes that "Mesozoic beds" of the main area described by Cairnes probably are wholly Lower Cretaceous. Some of the outlying areas may contain rocks that have been incorrectly correlated with the Cretaceous rocks of the main area.

Stratigraphic description.—The Lower Cretaceous rocks of the upper Yukon region lie in a belt 10 miles or more wide, extending along both sides of the Yukon from Coal Creek to a place about 4 miles above Logan Creek, where it passes to the north of the river. The northeastern extension of this belt has been recognized along the Canada-Alaska boundary, where the main part of its area lies between latitudes 65° 22′ and 66° 5′ north.

The Lower Cretaceous rocks of the area south of the Yukon were described by Brooks and Kindle[25] as follows:

[20] Cairnes, D. D., Geology of a portion of the Yukon-Alaska boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Summary Rept. for 1911, No. 1218, pp. 27, 31–32, 1912.

[21] Cairnes, D. D., Geology of a portion of the Yukon-Alaska boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Summary Rept. for 1912, No. 1305, p. 11, 1914.

[22] Cairnes, D. D., Geological section along the Yukon-Alaska boundary line between Yukon and Porcupine Rivers: Geol. Soc. America Bull., vol. 25, pp. 201–202, 1913.

[23] Cairnes, D. D., The Yukon-Alaska international boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 103–107, 1914.

[24] Idem, p. 106.

[25] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon. Alaska: Geol. Soc. America Bull., vol. 19, p. 306, 1908.

The Lower Cretaceous of the upper Yukon comprises a series of closely folded rocks characterized by a large amount of silica. They include primarily siliceous slates, slaty sandstones, and quartzites, with which are associated some argillites and pyroclastics. One heavy bed (50–75 feet thick) of massive tuffaceous conglomerate was observed within the Mesozoic area about 5 miles below Washington Creek, but may be an infolded older or younger terrane. The pebbles of this conglomerate, which are chiefly limestone, are well rounded, and some are 2 feet in diameter. The dominating rock type of the Lower Cretaceous is a siliceous slate or quartzite, sometimes interbedded with a clay slate. These rocks are usually pyritiferous and iron-stained when weathered. Three miles below Washington Creek there is a series of beautifully banded slates and quartzites. Here the brittle quartzite is broken by a series of fractures at right angles to bedding, while the same movement has in large measure been taken up in the cleavage of the slate. A quartz filling, sometimes carrying pyrite, is not uncommon along these fractures. In at least one instance it appears to be established that quartz veins cutting these Cretaceous rocks are auriferous. This conclusion is not without importance in its bearing on the age of the mineralization which produced the auriferous deposits of the Yukon.

These rocks in a general way strike easterly and northeasterly, but there are many local variations. They are usually closely folded, and no determination of thickness, which probably does not exceed a few thousand feet, could be made. On Washington Creek they appear to rest unconformably on the Devonian and in turn are unconformably overlaid by the Tertiary beds. Near Coal Creek the *Aucella*-bearing beds seems to underlie the upper Carboniferous limestone, which has apparently been thrust over them.

The thickness of these rocks is apparently several thousand feet, but the obliteration of the bedding in many places by slaty cleavage and the presence of crumpled zones in which the detailed structure is unsolved and of faults on which the amount of movement is not determined detract from the value of any estimates of thickness.

The Lower Cretaceous rocks exposed along the boundary, according to Cairnes,[26] consist mainly of shales, sandstones, greywackes, conglomerates, slates, and quartzites which have an aggregate thickness of at least 4,000 feet." They "overlie the Upper Carboniferous or Permian sediments" and "are the most recent consolidated sediments along the portion of the one hundred and forty-first meridian here under consideration."

Age and correlation.—The known fossils of the Lower Cretaceous rocks of the upper Yukon region include a few small lots of marine invertebrates and one plant and are represented in the following table. Concerning lots 18, 19, and 21, Stanton[27] said:

The reference of these three lots of fossils provisionally to the Lower Cretaceous is made with the same reservation that has so often been expressed when similar collections containing *Aucella* and only a few associated forms have been submitted from this and other areas in Alaska—that is, while the *Aucella*

[26] Cairnes, D. D., The Yukon-Alaska international boundary between Porcupine and Yukon Rivers: Canada Geol. Survey Mem. 67, pp. 103–107, 1914.

[27] Stanton, T. W., cited by Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, p. 307, 1908.

itself is indicative of probable Cretaceous age, closely related species are known in the Jurassic, and it may be that all of the *Aucella* beds of Alaska are Jurassic.

Fossils from the Lower Cretaceous rocks of the upper Yukon region [a]

	69	18	19	21	1509A	1509B
Chondrites heerii Eichwald [b]						×
Pinna		×				
Inoceramus		×		×		
Inoceramus?					×	
Aucella cf. A. crassicollis Keyserling	×		×			
Aucella				×		
Aucella?		×				
Pecten		×				
Perisphinctes?		×				

[a] Identified by T. W. Stanton except as indicated.
[b] Identified by F. H. Knowlton.

69. Washington Creek 6 miles above mouth. A. J. Collier, 1902.

18. South bank of the Yukon 400 yards below Glen Creek. E. M. Kindle, 1906.

19. North bank of the Yukon 6 miles above Charlie Village. E. M. Kindle, 1906.

21. South bank of the Yukon 1½ miles below Sam Creek. E. M. Kindle, 1906.

1509A. Yukon River 8½ miles above Washington Creek. Eliot Blackwelder, 1915.

1509B. South bank of the Yukon half a mile above mouth of Charlie Creek. Eliot Blackwelder, 1915.

UPPER CRETACEOUS

SHALE, SANDSTONE, AND CONGLOMERATE NEAR SEVENTYMILE RIVER

Historical review.—The Upper Cretaceous rocks of the upper Yukon region were included by Spurr [28] as part of the rocks which he described as the Kenai "series." The part of these beds which is now known to be Upper Cretaceous comprises those "about 25 miles below Mission Creek." Spurr's description of the rocks at this locality is very brief, consisting merely of a statement that there is conglomerate associated with shale and sandstone containing abundant leaf impressions. A list of species determined by F. H. Knowlton is given, also a discussion by Knowlton [29] of the plants from this and other localities, part of which are Tertiary.

These rocks were included by Brooks [30] in the "Tertiary rocks" without specific mention of the beds now known to be Upper Cretaceous, other than a citation of Spurr's description of the basal member near the mouth of Mission Creek.

[28] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 185, 192, 1898.

[29] Knowlton, F. H., Report on a collection of fossil plants from the Yukon River, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 194–196, 1898.

[30] Brooks, A. H., The coal resources of Alaska: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, p. 536, 1902.

The Upper Cretaceous locality at the mouth of Seventymile River was visited in 1902 by Collier, who collected plants now known to be Upper Cretaceous. The rocks at this locality were not then recognized as Cretaceous and were included by Collier in the general description [31] of the Tertiary rocks of the district, with an additional statement [32] that "a great thickness of Kenai sandstone, not known to be coal bearing, is exposed at the mouth of Seventymile River."

The description of the section on the upper Yukon by Brooks and Kindle contains no specific mention of any known Upper Cretaceous rocks, but the account of the Tertiary rocks [33] contains a suggestion that the rocks described as Tertiary may include some Cretaceous beds. It is also stated [34] that "in some instances the rocks are well indurated, being made up of hard conglomerate, sandstone, and sandy and clayey shales or slates, while in others the sandstones are almost unconsolidated and the argillites very little indurated." This statement suggests to the writer a possible unrecognized unconformity between more indurated Upper Cretaceous and less indurated Tertiary rocks. The writer also believes that some of the rocks referred to the Nation River formation by Brooks and Kindle, which are said [34] to resemble the more indurated Tertiary conglomerate, sandstone, and shale, may possibly be Upper Cretaceous.

The notes by Prindle [35] on the Tertiary rocks of the Fortymile quadrangle, in which the Upper Cretaceous locality near the mouth of Seventymile River lies, contain no mention of the rocks at the Upper Cretaceous locality but describe the other more indurated supposed Tertiary rocks of the quadrangle, part of which, as suggested above, may possibly be Upper Cretaceous. The same belt of Tertiary rocks extends westward into the Circle quadrangle and has been described by Prindle.[36] The rocks of this part of the belt may perhaps also contain some undifferentiated Upper Cretaceous members, but there is no special reason to suspect their presence, except that some of the beds are described as more thoroughly indurated than the others. The same publication contains a description [37] of a few areas of conglomerate and arkosic sandstone near the main divide of Charley, Goodpaster, and Salcha rivers, which

[31] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 15–17, 1903.

[32] Idem, p. 28.

[33] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, pp. 307–309, 1908.

[34] Idem, p. 308.

[35] Prindle, L. M., The Forty-mile quadrangle, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 375, pp. 23–26, 1909.

[36] Prindle, L. M., A geologic reconnaissance of the Circle quadrangle, Alaska: U. S. Geol. Survey Bull. 538, pp. 33–34, 1913.

[37] Idem, p. 32.

Prindle believes to be possibly Upper Cretaceous. No conclusive evidence of the age of these rocks was obtained. They are not known to contain any fossils except "poorly preserved plant remains," which were apparently not collected.

Stratigraphic description.—The Upper Cretaceous rocks of the upper Yukon region are exposed in the cliffs on the south bank of the Yukon just below the mouth of Seventymile River. These cliffs are composed of shale, sandstone, and conglomerate striking northwest and dipping about 40° S. The rocks consist for the most part of an alternation of thin beds of sandy shale and sandstone, but there are some beds of conglomerate 10 feet or more thick. The shale contains abundant fossil plants, of which collections were made at the mouth of the small creek 1½ miles below the mouth of Seventymile River and at several neighboring localities on the bank of the Yukon. At the north end of the cliffs there are exposures of supposed Carboniferous limestone, which appears to underlie the Cretaceous rocks unconformably. At the south end of the cliffs there are also exposures of supposed Carboniferous limestone having an attitude discordant with that of the Cretaceous rocks, the limestone striking N. 25° E. and dipping 25° SE. There is evidently either a fault or an overturning of the rocks at this place—probably a fault.

A belt of Tertiary clay, sandstone, shale, and conglomerate that are also plant-bearing lies in the valley of Seventymile River not far west of these Cretaceous rocks and possibly adjoins them, but the intervening area has not been examined, and the relation of the Cretaceous to the Tertiary rocks is not known. The Tertiary rocks of Seventymile River have been described by Brooks and Kindle[39] and also by Prindle[40] as including beds that differ very much in degree of induration. Possibly the more indurated of the supposed Tertiary rocks of Seventymile River may be the western extension of these Upper Cretaceous beds.

Age and correlation.—The Upper Cretaceous rocks near Seventymile River have yielded no fossils other than the plants which are described and discussed by Hollick in a monograph now in preparation and are listed in the following table. These plants indicate a correlation with the Kaltag formation, which constitutes the upper coal-bearing division of the Upper Cretaceous section on the lower Yukon:

[39] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, p. 310, 1908.

[40] Prindle, L. M., The Fortymile quadrangle, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 375, p. 25, 1909.

Upper Cretaceous fossils from upper Yukon region [a]

	1555	2973	3243	6815	7407	7408
Podozamites lanceolatus (Lindley and Hutton) C. F. W. Braun			×	×	×	×
Ginkgo sp		×				
Cephalotaxopsis, n. var	×			×		
Cephalotaxopsis sp		×			×	×
Nymphaeites, n. sp			×			
Castaliites sp						×
Menispermites, n. sp	×					
Platanus sp					×	×
Credneria?, n. sp			×			
Protophyllum? sp	×					
Pseudoaspidiophyllum, n. gen. and sp			×			
Pseudoaspidiophyllum, n. gen. and sp				×		
Pseudoprotophyllum, n. gen. and sp			×			
Pseudoprotophyllum, n. gen. and sp	×					
Pseudoprotophyllum, n. gen. and sp			×			
Pseudoprotophyllum, n. gen. and sp			×			
Pseudoprotophyllum, n. gen. and sp			×			
Pseudoprotophyllum sp					×	
Hedera platanoidea Lesquereux				×		

[a] Identified by Arthur Hollick.

1555. Yukon River 25 miles below Mission Creek. J. E. Spurr, 1896.

2973 (57). Left (south) bank of the Yukon 2 miles below mouth of Seventymile River. A. J. Collier, 1902.

3243 (3 AH 4). Left (south) bank of Yukon River just below Seventymile River. Arthur Hollick, 1903.

6815. South bank of Yukon River at mouth of draw 1½ miles below Seventymile River. G. C. Martin, 1914.

7407. Same locality as 6815. G. C. Martin, 1919.

7408. South bank of Yukon River half a mile below next gulch below Seventymile River. G. C. Martin, 1919.

RAMPART-TANANA DISTRICT

GENERAL FEATURES

The Cretaceous rocks of the Rampart-Tanana district include marine Lower Cretaceous quartzite and slate and marine Upper Cretaceous sandy shale. The Lower Cretaceous rocks overlie Silurian and Devonian metamorphic rocks, are of undetermined thickness, and have yielded only a few fragmentary fossils, chiefly *Aucella.* The Upper Cretaceous rocks probably rest unconformably on the Lower Cretaceous slate and quartzite, consist of black, rather massive carbonaceous sandy shale, probably 200 or 300 feet thick, and contain marine mollusks and poorly preserved fossil plants. Tertiary rocks, although present elsewhere in the district, are absent at this locality, and the only beds known to overlie the Upper Cretaceous rocks are recent unconsolidated deposits.

LOWER CRETACEOUS

QUARTZITE AND SLATE NEAR QUAIL CREEK

Historical review.—The Lower Cretaceous quartzite and slate of the Rampart-Tanana district were described by Eakin [41] as "slates,

[41] Eakin, H. M., A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pp. 20–21, 1913.

quartzites, and schists (Cretaceous and older)." The description includes a general discussion of the lithologic character of the rocks and a statement by T. W. Stanton concerning some fossils which he regards as probably Lower Cretaceous or uppermost Jurassic. Eakin says that the fossils were obtained from one of the quartzites which he believes to be among the lower members of the assemblage. The fossils were obtained near the headwaters of the north fork of Quail Creek in an area mapped by Prindle[42] as the Tonzona group, very near localities where Devonian and Silurian fossils have been collected. It had been previously suggested by Brooks[43] that this quartzite is possibly Lower Cretaceous. These rocks are possibly the source of some fucoids which Brooks[44] listed with Tertiary fossil plants but which he obtained near the Cretaceous localities in an area that he mapped as undifferentiated Paleozoic rocks.[45]

The Lower Cretaceous may also be represented by some slate, sandstone, and conglomerate lying between Baker Creek and Tolovana River, which were described as the "Nilkoka beds" by Brooks,[46] who originally referred them to the Paleozoic but afterward[47] suggested that "it now seems more likely that they are Cretaceous." Brooks still later[48] correlated these rocks with the Tonzona group of the Alaska Range, which is considered Devonian or Silurian. These rocks were described by Eakin[49] under the heading "slates, sandstones, and conglomerates" and considered probably early Mesozoic.

Stratigraphic description.—The Lower Cretaceous rocks of the Rampart-Tanana district have not been described in detail. Lower Cretaceous fossils were obtained from a bed of quartzite which was regarded by Eakin as among the lowest members of an assemblage of slate, quartzite, and schist which he considered largely if not entirely of Mesozoic age. On the other hand, Prindle, on the evidence of some fossils from other members of what seems to be the same assemblage of rocks, considered them probably Devonian. The writer believes that the quartzite and slate that contain the Lower Cretaceous fossils are at the top of the slate, quartzite, and schist, which are probably chiefly Paleozoic.

[42] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 44–45, pl. 8, 1913.

[43] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 93, 1911.

[44] Idem, p. 101.

[45] Idem, pl. 9.

[46] Brooks, A. H., A reconnaissance in the Tanana and White River basins, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, p. 472, 1900.

[47] Brooks, A. H., The coal resources of Alaska: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, p. 530, 1902.

[48] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 75, 1911.

[49] Eakin, H. M., op. cit., p. 19.

Age and correlation.—The fossils that have been obtained from the Lower Cretaceous quartzite near Quail Creek are listed in the table below. Concerning the fossils of lot 7241 Stanton[50] said:

The collection consists of quartzite filled with fragmentary imprints of pelecypods, which were apparently broken up before they were embedded. There is only a single specimen in the lot which shows fairly well the form of the shell, and this seems to be referable to the genus *Aucella*, though it is an internal cast of the left valve which does not show the distinctive features of the genus. If the provisional identification of this specimen is correct the horizon is either Lower Cretaceous or uppermost Jurassic.

Stanton also made the following statement[50] concerning the fossils of lot 11390:

The specimens of *Aucella* are somewhat better than those previously obtained from the same beds in this neighborhood, but they are all immature. They suggest Lower Cretaceous rather than Upper Jurassic.

Lower Cretaceous fossils from quartzite near Quail Creek[a]

	27	7241	18AO1	11390	11391
Chondrites heerii Eichwald	a		a		
Pentacrinus				b	
Aucella crassicollis Keyserling?		b		b	
Aucella?					b
Pecten?				b	
Pelecypods		b			

[a] a, Identified by F. H. Knowlton; b, identified by T. W. Stanton.

27. Southeast of camp of August 12, on ridge about 2 miles east of Little Minook Creek. A. H. Brooks, 1902.

7241 (11 AE 5.) "Little Minook-Quail Creek divide," half a mile below trail crossing. H. M. Eakin, 1911.

18 AO 1. Peak east of Hunter Creek, about 3 miles southeast of the mouth of Fortyseven Pup. R. M. Overbeck, 1918.

11390 (22 AMt 113). 3.7 miles S. 78° W. of mouth of Quail Creek. J. B. Mertie, 1922.

11391 (22 AMt 85). 5.37 miles N. 79° W. of mouth of Quail Creek. J. B. Mertie, 1922.

UPPER CRETACEOUS

SHALE NEAR WOLVERINE MOUNTAIN

Historical review.—The Cretaceous rocks in the Rampart district were first recognized by Prindle,[51] who described the sandstone and shale of Wolverine and Lynx mountains. The description states that the rocks are "black, rather massive, impure sandstones and shales," contain "fragments of dicoyledonous leaves and part of an indeterminable bivalve," "rest on the upturned edges of the older Silurian or Devonian rocks and have themselves undergone considerable deformation," "resemble the Upper Cretaceous rocks which occur lower down the Yukon," and "are entirely different from the Kenai rocks near Rampart and are referred provisionally to the Cretaceous."

[50] Unpublished notes.

[51] Prindle, L. M., Geography and geology [of Rampart gold placer region, Alaska]; U. S. Geol. Survey Bull. 280, pp. 17, 22, 1906.

A subsequent description of these rocks, based on additional field studies by Prindle,[53] contains a brief statement of the lithologic character of the rocks accompanied by lists and a discussion by Stanton of marine invertebrate fossils from Wolverine Mountain and Quail Creek. A brief reference to the occurrence of these rocks was made by Brooks and Kindle.[54] A later description by Prindle[55] contains no mention of the rocks on Lynx Mountain, which had previously been erroneously correlated on lithologic grounds with the rocks on Wolverine Mountain. A brief description of these rocks, based on the observations of Prindle, has been given by Brooks.[56] and a brief mention of them was made by Eakin,[57] who suggested that they may extend southwestward from Wolverine Mountain into the area of the Rampart quadrangle.

Stratigraphic description.—The Upper Cretaceous rocks of Wolverine Mountain include a basal conglomerate about 10 feet thick, containing pebbles of quartzite and black slate, overlain by several hundred feet of rather massive black sandy shale, fine-grained black shale, and sandstone. The underlying rocks are quartzite and shale that are regarded by Prindle as Paleozoic and by Eakin as probably mainly Lower Cretaceous. These divergent opinions are based on the presence, in near-by localities, of both Lower Cretaceous and Devonian or Silurian fossils. There is no question that the rocks surrounding Wolverine Mountain include both Lower Cretaceous and Devonian or Silurian beds. No conclusive evidence is at hand as to whether the Lower Cretaceous or the Paleozoic beds immediately underlie the Upper Cretaceous rocks. The only rocks that are younger than these Upper Cretaceous beds and are in contact with them are igneous intrusives. Tertiary strata are present in the district, but they do not overlie the Upper Cretaceous beds.

Age and correlation.—The fauna and flora of the Upper Cretaceous rocks of Wolverine Mountain, represented in the following table, include some marine invertebrates and a few poorly preserved plants. Fragments of dicotyledonous leaves and a part of an indeterminable bivalve were collected by Prindle from these rocks in 1904. Partly on that basis and partly on their lithologic character he assigned them to the Cretaceous. In 1907 Prindle obtained additional fossils, including both marine invertebrates and plants. No report on these fossil plants or on those collected in 1904 has been

[53] Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 337, pp. 16, 23–24, 1908.

[54] Brooks, A. H., and Kindle, E. M., Paleozoic and associated rocks of the upper Yukon, Alaska: Geol. Soc. America Bull., vol. 19, p. 307, 1908.

[55] Prindle, L. M., A geologic reconnaissance of the Fairbanks quadrangle, Alaska: U. S. Geol. Survey Bull. 525, pp. 33, 34, 47–48, 1913.

[56] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, pp. 51, 55, 93, 130, 1911.

[57] Eakin, H. M., A geologic reconnaissance of part of the Rampart quadrangle, Alaska: U. S. Geol. Survey Bull. 535, pp. 21, 24, 1913.

published. The following statement concerning the marine invertebrates collected by Prindle in 1907 was furnished by Stanton:[58]

While the fossils are fairly well preserved, they have been considerably distorted, so that it is not practicable to make specific determination. The better-preserved forms appear to be undescribed. The following list will show the forms recognized in each lot.

These fossils evidently all belong to practically a single horizon, which is confidently referred to the Upper Cretaceous. * * * The species of *Inoceramus* is very likely one that has been previously found on the Yukon, but the specimens in the present collection are too imperfect to serve as the basis for a positive identification. The most important forms are ammonites, which make up the bulk of the collection and which I have referred, in some cases doubtfully, to the genus *Pachydiscus.* These are unquestionably Upper Cretaceous types.

The presence of *Sequoia reichenbachi* and *Inoceramus* cf. *I. labiatus* indicates that the Upper Cretaceous rocks of Wolverine Mountain are to be correlated with the Nulato formation of the lower Yukon.

Upper Cretaceous fossils from Rampart-Tanana district [a]

	4AP306	7AP263	4278, 7AP271	4279	4280	8900	7577, 11392	7576
Fern							a	
Podozamites lanceolatus eichwaldi Heer?								a
Ginkgo			b					
Sequoia reichenbachi (Geinitz) Heer?								a
Taxodium?			b					
Populus	b							
Viburnum								a
Dicotyledons			b					
Stems or bark	b							
Vegetable fragments		b						
Hemiaster?			c	c		c		
Nucula						c		
Nemodon						c		
Cucullaea			c	c				
Inoceramus cf. I. labiatus Schlotheim			c					
Pecten			c			c		
Pleuromya			c					
Lucina			c					
Natica						c		
Pachydiscus			c	c	c			
Pachydiscus?			c	c		c		
Ammonite							c	

[a] a, Identified by Arthur Hollick; b, identified by F. H. Knowlton; c, identified by T. W. Stanton.

4AP306. Southeast spur of Wolverine Mountain, 2.92 miles S. 58° W. of mouth of Quail Creek. L. M. Prindle, 1904.

7AP263. Near Wolverine Mountain (?). L. M. Prindle, 1907.

4278 (7AP271). Southeast spur of Wolverine Mountain, 2.6 miles S. 53° W. of mouth of Quail Creek. L. M. Prindle, 1907.

—— (7AP271). Same locality as 4278. L. M. Prindle, 1907.

4279 (7AP278). Ridge on left side of south fork of Quail Creek. L. M. Prindle, 1907.

4280 (7AP279). Right side of south fork of Quail Creek. L. M. Prindle, 1907.

[58] Stanton, T. W., cited by Prindle, L. M., The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: U. S. Geol. Survey Bull. 337, p. 24, 1908.

8900. South fork of Quail Creek about 1 mile above main forks. G. C. Martin, 1914.

7577 (22AMt105b). About 3⅛ miles S. 69° W. of mouth of Quail Creek. J. B. Mertie, 1922.

11392 (22AMt105a). Same locality as 7577. J. B. Mertie, 1922.

7576 (22AMt79). About 7⅔ miles N. 44° E. of Eureka. J. B. Mertie, 1922.

LOWER YUKON REGION

GENERAL FEATURES

The Cretaceous rocks of the lower Yukon region are exposed at many localities in the north bank of the Yukon between Melozi and Andreafski. They consist of probably several thousand feet of Upper Cretaceous shale, sandstone, and conglomerate, some of which are marine and some of which are of brackish or fresh water origin and include coal-bearing members. The stratigraphic sequence is believed to be as follows:

Generalized section of Upper Cretaceous rocks on lower Yukon River

	Feet
Kaltag formation: Coal-bearing rocks consisting of fresh-water sandstone, shale, and coal beds with possibly some thin marine members. Contains fossil plants, fresh-water invertebrates, and perhaps a few marine invertebrates	800+
Nulato formation: Marine sandstone and shale. Contains marine invertebrates and a few plants	3,000?
Melozi formation: Fresh-water shale and sandstone. Contains fossil plants and fresh-water invertebrates	1,000+
Ungalik conglomerate: Conglomerate, sandstone, and sandy shale. Contains worm tubes, trails, and vegetable detritus	3,000

In the northern part of the region the Upper Cretaceous rocks adjoin and are believed to rest directly upon early Paleozoic metamorphic rocks. In the southern part of the region they overlie upper Carboniferous greenstone and associated sediments. The beds that have been observed to overlie the Upper Cretaceous rocks are unconsolidated Quaternary deposits, but supposed Tertiary volcanic rocks occur near some of the Upper Cretaceous rocks and are believed to be the next succeeding formation.

UPPER CRETACEOUS

Historical review.—The first mention of the rocks of the lower Yukon region now referred to the Upper Cretaceous is contained in a short article by Dall,[59] in which there are statements of the kinds of rock exposed in the river bank, with mention of the presence of fossil mollusks and vegetable remains. In a later article[60] Dall

[59] Dall, W. H., Explorations in Russian America: Am. Jour. Sci., 2d ser., vol. 45, pp. 96–99, 1868.

[60] Dall, W. H., Note on Alaska Tertiary deposits: Am. Jour. Sci., 3d ser., vol. 24, pp. 67–68, 1882.

states that the brown sandstone with marine fossils at Nulato and the underlying leaf-bearing shale are Miocene. A brief description of the rocks exposed in the bank of the Yukon below the mouth of Melozi River has been given by Russell.[61] In a subsequent, more extensive discussion of these rocks Dall and Harris[62] described them as consisting of the Nulato sandstone and the Kenai "group." The Nulato sandstone was described as a brownish marine sandstone, which extends along the river from Kaltag to Koyukuk Mountain and which lies conformably on the bluish sandstone of the Kenai "group." This description was also repeated by Dall[63] with little change.

Additional observations on the Upper Cretaceous rocks of the lower Yukon region were made by Spurr in 1896. Spurr described these rocks as the Kenai "series"[64] and the Nulato sandstones,[65] both of which he referred to the Tertiary. The description contains a detailed record of local observations by Spurr and is accompanied by a statement by Knowlton[66] on some fossil plants.

The exposures in the bank of the Yukon between Nulato and the mouth of the Koyukuk were observed by Schrader in 1899, and marine mollusks, which were determined by Stanton as Upper Cretaceous, were collected. Schrader's report makes mere mention[67] of the fact that Upper Cretaceous fossils were recognized. The Nulato sandstone, from which these fossils were obtained, and some of the contained coal beds are briefly mentioned,[68] but no reference is made to the fact that the fossils show the Nulato sandstone to be Upper Cretaceous and not Miocene. In a later report Schrader gave a list of these fossils,[69] without a description of their precise occurrence, under the heading "Upper Cretaceous on the Koyukuk." He subsequently gave the list again,[70] with a correct statement of their occurrence, in a discussion of the correlation of the Nanushuk "series" of the Arctic coast. Further reference to the Upper Cretaceous fossils collected by Schrader near the mouth of the Koyukuk

[61] Russell, I. C., Notes on the surface geology of Alaska: Geol. Soc. America Bull., vol. 1, p. 108, 1890.

[62] Dall, W. H., and Harris, G. D., Correlation papers—Neocene: U. S. Geol. Survey Bull. 84, pp. 233, 246–248, 253–254, 258, 1892.

[63] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 817–818, 838, 844–845, 849, 860, 862, 1896.

[64] Spurr, J. E., Geology of the Yukon gold district, Alaska: U. S. Geol. Survey Eighteenth Ann. Rept., pt. 3, pp. 189–191, 193, 194, 1898.

[65] Idem, p. 196.

[66] Knowlton, F. H., Report on a collection of fossil plants from the Yukon River: Idem, pp. 194–196.

[67] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk Rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, p. 477, 1900.

[68] Idem, pp. 478, 485–486.

[69] Schrader, F. C., Geological section of the Rocky Mountains in northern Alaska: Geol. Soc. America Bull., vol. 13, p. 248, 1902.

[70] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, p. 81, 1904.

was made by Brooks,[71] who gave a list of the fossils as determined by Stanton, and stated that the Nulato sandstone is "closely associated with Upper Cretaceous beds" and that "the horizon of the coals in the vicinity of Nulato has not been definitely determined."

The Upper Cretaceous coal-bearing rocks of the Yukon were studied in considerable detail by Collier in 1902. Collier collected fossils, including plants and marine and fresh or brackish water invertebrates, at many localities. The marine invertebrates and some of the plants were at once recognized as Upper Cretaceous. Some of the plants were for a time regarded as Tertiary and others as possibly Lower Cretaceous, but they are now all regarded as Upper Cretaceous. The fresh or brackish water fossils collected by Collier are not distinctive, but they too are doubtless Upper Cretaceous, as they occur interbedded with the other forms.

In a preliminary report[72] on his investigations, dealing chiefly with the occurrence and character of the coal beds, Collier states that the coal-bearing beds of the lower Yukon consist "of sandstones, shales, and conglomerates, which probably form an uninterrupted sedimentary series, ranging in age from the Middle Cretaceous to the upper Eocene, and hence include both the Nulato and the Kenai series." In a later report these rocks are described by Collier[73] as including three divisions—fresh-water cycad-bearing beds near Nulato, which are "probably assignable to the Lower Cretaceous"; Upper Cretaceous marine and fresh-water (coal-bearing) sandstone, conglomerate, and shale with "a marine invertebrate fauna of Upper Cretaceous age" and fossil plants "assigned by Knowlton to the Upper Cretaceous"; and a succeeding horizon, "called the Kenai series," of upper Eocene age, with abundant plant remains, extensively developed near Nulato, where "its relation to the Upper Cretaceous seems to be one of conformity." In this report Collier also gave detailed descriptions[74] of the strata exposed at and near the known coal beds.

As the result of a preliminary study of the fossil plants collected by Collier and of additional collections made by Hollick in 1903, Knowlton[75] stated that the fossil plants obtained below Rampart "indicate that the age is either undoubted Cretaceous or doubtful Tertiary. The Cretaceous plants include cycads of several genera, conifers, and many dicotyledons, the combination resembling mostly the Middle and Upper Cretaceous flora of Bohemia." A summary

[71] Brooks, A. H., The coal resources of Alaska: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, pp. 529, 535, 555–556, 1902.

[72] Collier, A. J., Coal resources of the Yukon Basin, Alaska: U. S. Geol. Survey Bull. 213, 1903, pp. 276–283.

[73] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 15, 17, 1903.

[74] Idem, pp. 19–20, 46–58, 65.

[75] Knowlton, F. H., Fossil floras of the Yukon: Science, new ser., vol. 19, pp. 733–734, 1904.

of the results of the field investigations of Collier and Hollick and of the studies of their collections by Stanton and Knowlton has been given by Brooks.[76]

Additional field studies and collections of fossils were made by W. W. Atwood and H. M. Eakin in 1907, but no complete report on the work has been published, although some of the results have been used by the writers cited below, notably by Eakin and by Smith and Eakin, as well as by the present writer in this volume.

As a result of his earlier laboratory studies of all the fossil plants collected from the Cretaceous rocks of this region, Hollick[77] discussed briefly the broader aspects of the floras, without local details, and also made a general preliminary statement[78] dealing chiefly with age and correlation of the flora. He also referred to the Cretaceous plants in a discussion of the Tertiary flora of Alaska.[79]

A geologic reconnaissance from Nulato to the head of Norton Bay was made by P. S. Smith and H. M. Eakin in 1909. Their report contains much information concerning the Upper Cretaceous rocks,[80] not only of the area between Yukon River and the head of Norton Bay, which was the special field of the investigation, but of the exposures along the Yukon, especially between Nelozi and Kaltag. In the description of the latter area the observations of previous investigations were largely used. The Cretaceous rocks described by Smith and Eakin are divided into two named units—"a basal conglomerate called * * * the Ungalik conglomerate and an overlying group of sandstones and shales called the Shaktolik group. The Shaktolik group is separated into two divisions, the lower, distinguished by a preponderance of sandstones over shale, and the upper, in which shales are in excess."

Brief mention of the Cretaceous rocks exposed along the Yukon between Melozi and Nulato was made by Eakin,[81] who derived his information from his own observations in 1907 but gave no details.

In 1913 Eakin made a geologic reconnaissance of the region between Yukon and Koyukuk Rivers. The account of this investigation contains a rather extensive general description of the Cretaceous

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[76] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 236, 241–242, 1906.

[77] Hollick, Arthur, Discussion of the Cretaceous and Tertiary floras of Alaska: Washington Acad. Sci. Jour., vol. 1, p. 142, 1911.

[78] Hollick, Arthur, Preliminary correlation of the Cretaceous and Tertiary floras of Alaska: Geol. Soc. America Bull., vol. 24, p. 116, 1913.

[79] Hollick, Arthur, Results of a preliminary study of the so-called Kenai flora of Alaska: Am. Jour. Sci., 4th ser., vol. 31, pp. 327–330, 1911.

[80] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 54–60, 1911.

[81] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 23–24, 1914.

rocks,[82] which is based not only on Eakin's field studies in 1913, but also, so far as the area lying along the Yukon is concerned, on previous investigations, including his own observations in 1907. Reports by T. W. Stanton and F. H. Knowlton on fossils collected by Atwood and Eakin in 1907 between Melozi and the mouth of the Koyukuk are published for the first time.[83] It should be noted that although the section exposed along the Yukon is believed to be wholly Upper Cretaceous, the northern part of the area, along the Koyukuk, contains some Lower Cretaceous rocks.

The Upper Cretaceous rocks west of the Yukon between Anvik and Andreafski have been described by Harrington. The description [84] includes general accounts of the areal distribution, lithology, stratigraphy, structure, age, and correlation of the Cretaceous rocks of the whole region, together with detailed statements of their local features in each of the separate areas. The account of age and correlation includes statements by F. H. Knowlton and J. B. Reeside, jr., concerning the fossil plants and mollusks collected by Harrington and a general statement by Arthur Hollick concerning the fossil plants from all the localities on the lower Yukon.

The Upper Cretaceous section exposed between Melozi and Anvik was critically examined in 1921 by the writer, who also made some observations in the vicinity of Holy Cross in 1920. The results of these investigations, which have not hitherto been published, are incorporated in the following descriptions.

Stratigraphic description.—The Upper Cretaceous rocks exposed along Yukon River between Melozi and Andreafski consist of sandstone, conglomerate, and shale having an aggregate thickness of perhaps 8,000 feet. These beds include both marine and fresh-water members, and the latter contain some coal beds. The complete sequence is not exposed in any one section, there being numerous broad areas with no exposures, so that the full succession and thickness must be inferred from incomplete evidence. It is believed, however, that the rocks may be subdivided into the four formations shown in the table on page 395.

The Ungalik conglomerate, which is the basal division of the Upper Cretaceous rocks of the lower Yukon region, consists of conglomerate, sandstone, and sandy shale having an aggregate thickness of probably about 3,000 feet. It was described by Smith and Eakin [85] from exposures on Ungalik River east of Norton Bay. The

[82] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 41–50, 1916.

[83] Idem, pp. 47–48.

[84] Harrington, G. L., The Anvik-Andreafski region, Alaska: U. S. Geol. Survey Bull. 683, pp. 22–23, 26–35, 51, 1918.

[85] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pp. 55–57, 1911.

only fossils found in it are undetermined marine pelecypods, worm tubes, trails, and vegetable detritus.

The Melozi formation, here described for the first time from exposures on the north bank of the Yukon from 8 to 20 miles below Melozi telegraph station, overlies the Ungalik conglomerate with apparent conformity. It consists of fresh-water shale and sandstone at least 1,000 and possibly several thousand feet thick. It contains fossil plants and fresh-water invertebrates.

The Nulato formation, which overlies the Melozi formation with apparent conformity, consists of marine sandstone and shale probably about 3,000 feet thick. It is typically exposed in the northwest bank of the Yukon for 2 to 10 miles above Nulato. It includes the rocks which Dall[86] described as the Nulato sandstone. The Nulato formation contains marine invertebrates and a few fossil plants.

The Kaltag formation, here described for the first time from exposures on the northwest bank of the Yukon between Kaltag and the Williams mine, consists of coal-bearing rocks, including fresh-water sandstone, shale, and coal beds, with possibly some thin marine members. It overlies the Nulato formation with apparent conformity and is at least 800 feet thick. It contains fossil plants, fresh-water invertebrates, and perhaps a few marine invertebrates.

The most complete section of the Upper Cretaceous rocks of the lower Yukon is in the cliffs on the north bank of the river between Melozi and Louden. The section recorded on page 395 represents the sequence observed in these exposures, which are practically continuous, although the cliffs are masked in places by landslides and talus slopes and cut by faults of undetermined throw. Below Louden the exposures are less continuous, being interrupted by several broad concealed intervals. The several sections below Louden have been correlated with one another and with the more complete section between Melozi and Louden, on the basis of similarity in lithology and sequence. Descriptions of the exposures at several places and the reasons for the correlations are given below.

A fairly continuous section of Upper Cretaceous rocks is exposed in the north bank of the Yukon between Melozi River and Louden. The exposures begin at the western edge of the delta of Melozi River about 4 miles above Melozi telegraph station, but the Upper Cretaceous rocks extend about 6 miles farther east, where they rest upon Paleozoic metamorphic rocks. The base of the Upper Cretaceous rocks is not exposed in the river banks, but Eakin, who has studied the rocks in the area north of the river, says[87] that "the

[86] Dall, W. H., and Harris, G. D., Correlation papers—Neocene: U. S. Geol. Survey Bull. 84, pp. 233, 246–248, 253–254, 258, 1892.

[87] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 41–42, 1916.

base of the series, where recognized, is a massive conglomerate of coarse texture" and that "the basal conglomerate ranges in thickness in exposed sections from a few feet to about 60 feet."

The rocks exposed between the western edge of the delta of Melzoi River and the Melzoi telegraph station include fine sandy shale overlain by conglomerate and coarse sandstone. These beds, which have an aggregate thickness of perhaps 2,000 feet, are folded as shown in Figure 10.

The rocks for about 7½ miles below Melozi telegraph station consist of conglomerate and sandstone with some shale. The exposures in this interval, as shown in Figure 10, reveal several repetitions of the beds by folds and faults. These beds are probably 2,000 or 3,000 feet thick and are believed to be a repetition of those above the telegraph station.

The rocks described above are chiefly coarse, the sandy beds consisting of coarse grit with many pebbles and beds of conglomerate being numerous. Shale beds are few, thin, and for the most part sandy. These rocks may be regarded as dominantly conglomeratic, even though the conglomerate may not actually constitute the greater part of their thickness. These are the rocks which Smith and Eakin[88] correlated with the Ungalik conglomerate of the Norton Bay district. The conglomeratic beds on the Yukon have yielded no fossils except lot 4781, obtained 1 mile below Melozi, consisting of indeterminate marine pelecypods, and lot 2968 obtained 3 miles below Melozi, consisting of undetermined plants.

The Ungalik conglomerate was described by Smith and Eakin[89] as a fairly coarse conglomerate, several hundred feet thick, the type locality of which is on Ungalik River east of Norton Bay. The conglomerate at the type locality was correlated on the basis of lithologic similarity with the conglomerate of a large area 40 miles to the northwest, on the hills between Kwik and Tubutulik Rivers, which rests unconformably upon Paleozoic limestone and schist and late Paleozoic or Mesozoic greenstone. A similar correlation was made with the conglomerate of an area

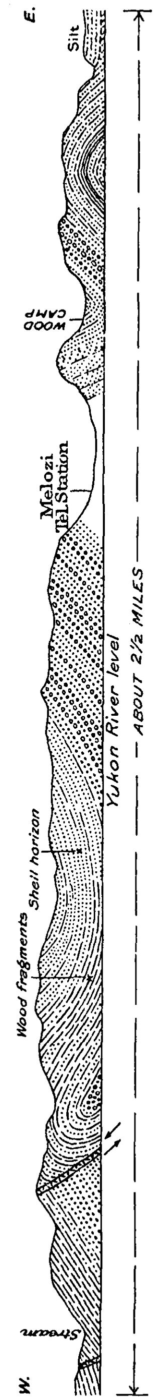

FIGURE 10.—Section of Upper Cretaceous rocks on Yukon River near Melozi. (By W. W. Atwood)

[88] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, p. 57, 1911.

[89] Idem, pp. 55–57.

35 miles north of the type locality, on the divide between Koyuk and Buckland rivers, and with the conglomeratic beds on the Yukon near the mouth of Melozi River, described above, which are about 140 miles east of the type locality.

The evidence on the age of the conglomerate on Ungalik River described by Smith and Eakin is that it underlies Upper Cretaceous sandstone without evidence of unconformity, whereas the conglomerate of the Tubutulik-Kwik area rests unconformably upon late Paleozoic or early Mesozoic rocks and contains poorly preserved plants that are apparently of Cretaceous age. No local evidence on the age of the conglomerate at the head of Koyuk River has been published.

The exposures in the river bank from 8 to 20 miles below the Melozi telegraph station constitute the second division of the Upper Cretaceous rocks of the lower Yukon, for which the name Melozi formation is herein proposed. These exposures reveal shale and

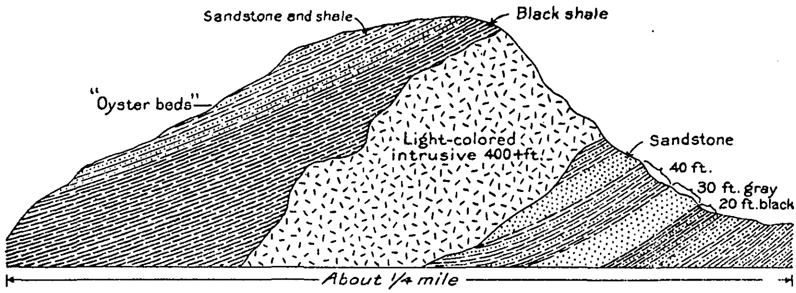

FIGURE 11.—Section of Upper Cretaceous rocks on Yukon River near Fossil Bluff. (By W. W. Atwood)

sandstone striking nearly parallel to the course of the river and dipping 25° or 30° NW. A computation from the average strike and dip indicates that the thickness may possibly be as much as 5,000 or 6,000 feet but that it is probably not more than 2,000 or 3,000 feet and may be not more than 1,000 feet. It was the writer's opinion, while studying this section in the field, that the thickness is not very great, and he is inclined to accept the smaller estimate. Even this may have to be reduced if there has been any duplication of the beds by faulting. The shale and sandstone of this formation, so far as known, are wholly nonmarine. They contain fossil plants and fresh-water invertebrates but have yielded no marine fossils.

At the bend of the river opposite the upper end of a long island about 5 miles below Good Island there is an abrupt change in the character and attitude of the rocks. The gray sandstone and shale exposed up the river are replaced by coarse reddish sandstone or arkose, conglomerate, highly indurated cherty shale, and shaly sandstone. These rocks dip at high angles. About 2 miles farther down

the river, at Fossil Bluff, are exposures of sandstone and shale containing both fresh-water and marine invertebrates (lots 2924, 2676, 2925, 4784). These rocks are regarded as belonging in the Nulato formation, which is described in greater detail on pages 404–408. The section at this place is shown in the accompanying sketches (figs. 11 and 12).

About a quarter of a mile down the river from this place and a quarter of a mile back from the shore are shale and sandstone with two or more thin coal beds.[90] Fossil plants were obtained from the roof of one of the coal beds (lot 2962) and also in float material between the mine and the river that is believed to have come from beds in the vicinity of the mine (lots 3252 and 4635). The coal and plant-

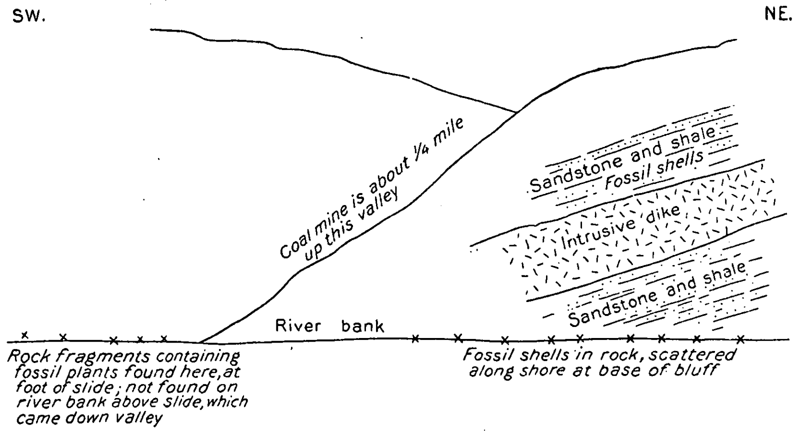

FIGURE 12.—Sketch showing position of fossiliferous beds near Fossil Bluff. (By Arthur Hollick)

bearing beds are believed to overlie the marine shale and sandstone of Fossil Bluff and to belong in the Kaltag formation.

From Louden to the mouth of the Koyukuk there are no exposures of consolidated rocks in the banks of the Yukon except at Bishop Rock. The exposures at this place consist of shale and sandstone, which apparently are conformable throughout. Fossil shells (lots 2AC244, 2926, 2927, and 4785) and fossil plants (lots 2977, 3257, and 4637) were obtained here. These rocks are believed to be correlatable in a general way with some of the marine sandstones above Louden and to belong in the Nulato formation.

From Bishop Rock to the mouth of Koyukuk River there are no exposures except terrace gravel. At the mouth of the Koyukuk are exposures of basalt that is intrusive into sandstone and conglomerate.

An almost continuous series of outcrops of Upper Cretaceous sandstone and shale extends along the north or west bank of the

[90] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 47–48, 1903.

Yukon from a point about 5 miles below Koyukuk village, or 3 miles above the Pickart coal mine, to Nulato. The attitude of the beds in these exposures, as they appear in the face of the cliffs, is shown in Figure 13. This section is drawn along the bank of the river at varying angles, amounting in general to about 45°, with the strike. It consequently shows only the general relations of the beds and not their true thickness.

The rocks from the upper end of the exposures to the creek just above the Pickart mine consist of yellowish sandstone and shale striking parallel to the river and dipping about 20° W. They yielded the fossil plants and marine invertebrates of lots 3253, 2679, and 2964. The beds south of the creek, which are believed to underlie immediately those north of the creek, yielded the marine inverte-

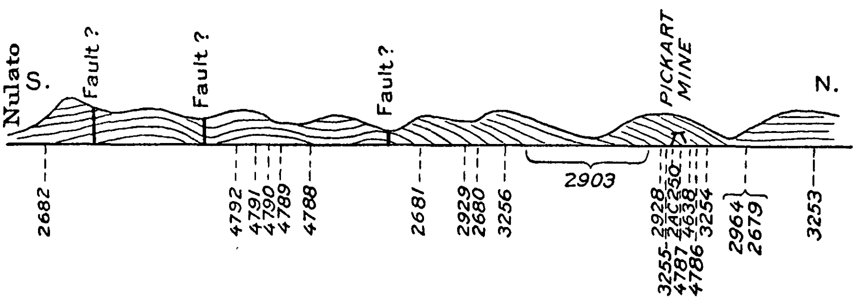

FIGURE 13.—Sketch showing general relations of Upper Cretaceous rocks between Pickart coal mine and Nulato

brates and plants of lots 3254, 4638, 4787, 2AC250, 3255, and 2928. These beds include the sandstone, shale, and coal shown in the following section, which was measured by W. W. Atwood. The upper end of this section is a quarter of a mile upstream from the Pickart mine, where the rocks strike N. 10° E. (magnetic) and dip 26° NW.

Section of Upper Cretaceous rocks near Pickart mine

	Ft.	in.
Alternating thin beds of sandstone and shale	50	
Yellow sandstone (conspicuous from river), conglomeratic at base	10	
Carbonaceous shale; contains 2-inch parting of coal in middle	8	
Sandstone	2	6
Carbonaceous shale		10
Clean bright lignite		5
Sandy shale	5	
Blue shale containing coal parting.		
Blue shale	6	
Sandstone, with shale lenses	2	
Blue shale	4	6
Alternating thin beds of sandstone and shale	8	
Blue shale, with coal lenses	5	
Shaly sandstone	2	

	Ft.	in.
Shale		6
Lignite lenses		4-6
Blue shale, interstratified with sandy shale	25	
Sandstone	1	
Blue shale	2	6
Sandstone	1	6
Blue shale	2	
Shaly sandstone	4	
Blue shale	1	6
Sandstone; weathers yellow; carries gastropod and lamellibranch fauna (lot 4786)		1-3
Blue shale	10	
Sandstone	1	
Blue shale, interstratified with sandy shale	17	
Sandstone	5	
Blue shale, interstratified with sandy shale	15	
Sandstone	2	
Blue shale, interstratified with sandy shale	12	
Sandstone	3	
Shale	2	
Sandstone, cross-bedded	3	
Blue shale	11	
Sandstone, cross-bedded	8	
Covered	100	
Sandstone	6	
Covered	20	
Sandy shale, interstratified with thin beds of sandstone	50	
Sandstone, interstratified with thin beds of shale	8	
Sandy shale		6
Coaly shale		6
Blue shale	5	
Sandstone, thin bedded	11	
Shale	12	
Sandstone	10	
Sandy shale, with thin beds of sandstone	50	
Sandstone	3	
Shale with thin beds of sandstone	100	
Sandstone with shale lenses	32	
Shale, with thin beds of sandstone; leaves (lot 4638). Above Pickart coal mine	6	
Sandstone	4	
Sandy shale	3	
Sandstone, with thin beds of shale	5	
Shales, interstratified with beds of sandstone, first above mine	60	
Heavy sandstone bed with shale pebbles (presumably clay pebbles on beach) and shale lenses	25	
Sandy shale	5	
Sandstone	2	
Shale with beds of sandstone (obscure)	50	
Sandstone	8	

	Ft.	in.
Shale and coal at Pickart mine, obscured by talus. Coal 2 feet, overlain and underlain by sandstone	20	
Sandstone	5	
Shales, interstratified with thin beds of sandstone	35	
Sandstone	5	
Shales, with thin beds of sandstone	18	
Sandstone, thin bedded	7	
Sandy shale, crushed	10	
Sandstone	14	
Shale, carbonaceous, with coaly lenses	3	
Sandstone	25	
Sandstone and shale, alternating thin beds	8	
Sandstone, thin bedded above, massive below, marine fossils (lot 4787)	50	
Shale	10	
Sandstone	4	
Shale, with coal stringers and ironstone nodules	25	
Sandstone, with thin beds of shale	20	
Shale, with beds of sandstone	25	
Sandstone, thin bedded	17	
Sandstone, carrying marine fauna	3	
Sandstone, in part thin bedded, in part massive. Some strata carrying shells	65	
	1,166	8

The rocks between the base of this section and Nulato include sandstone and shale that are repeated in the river bank by several gently undulating folds and possibly by faults. (See fig. 13.) They may include rocks somewhat older than any in this section, and they also probably include, near Nulato, some beds that are the equivalent of those near the Pickart mine.

The section from the vicinity of the Pickart mine to Nulato includes several thousand feet of marine sandstone and shale with fresh-water plant and coal-bearing rocks, interbedded with them in the upper part of the sequence. The marine sandstone and shale form the type section of the Nulato formation, and the overlying coal-bearing fresh-water beds belong in the Kaltag formation. The section is believed to be the general equivalent of the section from a point 5 miles below Good Island to Louden. The coal north of Fossil Bluff, above Louden, is believed to be correlatable with the coal at the Pickart mine and just above Nulato.

The rocks lying west of the Yukon in the hills between Nulato and Norton Sound were described by Smith and Eakin[91] as the Shaktolik group, in which they included such of the Mesozoic sedimentary rocks of the Nulato-Norton Bay district as are strati-

[91] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449. pp. 57–60, 1911.

graphically above the Ungalik conglomerate. The Shaktolik group was described as including two unnamed formations, which were differentiated in the description but not in mapping. The lower division of the Shaktolik group was described as consisting of sandstone and shale, the shale aggregating only a small part of the total thickness. These beds lie with apparent conformity upon the Ungalik conglomerate. The Nulato sandstone of previous reports and the associated coal-bearing rocks on the Yukon in the vicinity of Nulato were regarded as constituting undifferentiated members of undetermined position in the lower division of the Shaktolik group.

The upper division of the Shaktolik group was described as consisting predominantly of black shale but containing subordinate beds of calcareous sandstone and as having a thickness of possibly several thousand feet. It contains marine fossils of Upper Cretaceous age, and the general character of the fauna is very similar to that of the Upper Cretaceous beds of the lower Yukon.

Fossils from the Shaktolik group of the hills between Nulato and Norton Sound [a]

	6261	6262	6263	6264	6265	6266
Nucula?	×					
Cucullaea			×		×	
Inoceramus				×		
Ostrea	×	×				×
Thracia?	×		×			
Meekia?				×		
Meretrix?			×			
Pelecypods	×			×		

[a] Identified by T. W. Stanton.

6261 (9AE2). Gisana-Nulato divide, 10½ miles north and 14½ miles west from Nulato. P. S. Smith, 1909.

6262 (9AE3). Same horizon as 6261, 3½ miles west. P. S. Smith, 1909.

6263 (9AE4). 6 miles north and 20 miles west from Nulato. Probably 1,000 feet below 6262. P. S. Smith, 1909.

6264 (9AE5). About 50 feet below 6263, at same locality. P. S. Smith, 1909.

6265 (9AE6). 6 miles north and 23 miles west from Nulato. P. S. Smith, 1909.

6266 (9AE1). Gisana-Nulato divide, about 17 miles north and 4 miles west from Nulato. P. S. Smith, 1909.

Below Nulato there are no exposures for about 4 miles to the vicinity of the Bush coal mine, where, according to Collier,[92] the coal is contained in sandstone carrying fossil leaves. For about 4 miles below the Bush mine there are exposures of highly folded sandstone and shale. Fossil leaves were obtained (2978) about 1½ miles below the mine. The rocks in the vicinity of the Bush mine

[92] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, pp. 52–53, 1903.

are part of the Kaltag formation and are believed to be the general equivalent of the coal-bearing beds near the Pickart mine and just above Nulato.

At the Blatchford mine,[93] about 9 miles below Nulato, there are two thin beds of coal overlain by massive sandstone and underlain by sandstone and shale with fossil leaves (lot 3258). From the Blatchford mine to Kaltag the rocks strike northeast and dip northwest, exposing lower beds successively down stream. The rocks in this interval consist of shale and sandstone, which have yielded numerous collections of fossil plants and a few marine and fresh-water invertebrates. They dip at relatively high angles (15° to 50°) and would have a thickness of many thousand feet if there were no repetition by faulting. Several faults are known in this interval, but the amount of repetition is not known. The rocks between Nulato and Bluff Point, 21 miles below Nulato, have yielded only plants (lots 2978, 3258, 3260, 2980, 3261, 4639, 3259, 2981, 3262, and 3263) and fresh-water fossils (lots 2683 and 2932) and are believed to belong in the Kaltag formation, which forms the upper, coal-bearing member of the Cretaceous sequence. At Bluff Point and 2½ miles above Kaltag there are massive sandstones that have yielded marine fossils (lots 2931 and 4793). These rocks, which have a thickness of 2,500 feet in the bluff 2½ miles above Kaltag, are believed to be the oldest rocks exposed on this stretch of the river. Together with part but perhaps not all of the overlying plant-bearing sandstone and shale exposed between these two localities, which yielded the fossil plants of lots 3264, 2982, 3265, 2983, 3266, and 3267, they are probably to be correlated with the marine sandstone and shale exposed between the Pickart mine and Nulato and belong in the Nulato formation.

From 6 to 8 miles below Kaltag are exposures of sandstone dipping west. About 8 miles below Kaltag these beds yielded the fossil leaves of lots 2984, 3268, and 4640. At this place fragments of coal were seen in a slide. About 5 miles farther down the river, below an interval in which the rocks are concealed, is an outcrop of sandstone and coal. About 4½ miles farther down the river are exposures of sandstone and shale. Marine fossils (lot 2684) were found at this locality. The rocks in the next 10 miles of river bank are lava and tuff that are believed to be post-Cretaceous. Their relations to the Cretaceous rocks are not known. The rocks between Kaltag and this volcanic area are believed to belong to the upper coal-bearing division of the Cretaceous, which has been named the Kaltag formation.

[93] Collier, A. J., op. cit., pp. 53–55.

South of the volcanic area just described there are no rocks exposed in the river bank for about 12 miles. The next exposures are about 72 miles below Nulato, or 2 miles above the Williams coal mine. A series of bluffs beginning here extends to a point about a mile below the Williams mine. The coal bed at the Williams mine is about 3¼ feet thick and is interbedded with light-colored sandstone of different appearance from any Cretaceous rocks seen by the writer elsewhere on the river. The fossil plants of lot 2985 came from sandstone immediately above the coal. This sandstone is cut off from the apparently younger rocks up the river by a fault about half a mile above the mine. Collier[94] states that "the coal bed is overlain by at least 2,000 feet of sandstones, conglomerates, and black shales," a thickness which apparently includes only the rocks between the coal and the fault. About a mile above the mine occur sandstone and shale which yielded the fresh-water invertebrates of lots 2683, 2933, and 4795 and also the plants of lots 3269 and 4641. A little farther up the river, presumably higher in the sequence, the marine invertebrates of lot 4794 and the plants of lot 4642 were obtained. Possibly all these rocks belong in the Kaltag formation, but it is also possible that the rocks up the river from the fault are of lower undetermined stratigraphic position.

Igneous rocks crop out for several miles along the river, beginning about a mile below the Williams mine. Thence no rocks show on the bank for several miles, the next exposure noted consisting of igneous rocks about 15 miles below the Williams mine.

At coal mine No. 1, about 20 miles below the Williams mine, there are sandstone and shale containing one or more thin beds of coal. The fossil plants of lots 2986 and 3270 were obtained from sandstone a short distance stratigraphically above (down the river from) the coal.

About 13 miles below mine No. 1 there are exposures of sharply folded shale and sandstone with a bed of coal 8 or 10 inches thick. The fossil leaves of lots 3271 and 4643 were obtained at this place. For about 15 miles below this locality there are exposures of shale, sandstone, and conglomerate from which no fossils have been obtained. These exposures are considered, in the lack of evidence to the contrary, to belong with the neighboring coal-bearing exposure at locality 3271, in the Kaltag formation.

No exposures, other than gravel, were seen in the next 15 miles, or as far as the upper end of Hall Rapids, about 30 miles above Anvik. The exposures at Hall Rapids consist of tuff which Collier[95]

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[94] Collier, A. J., The coal resources of the Yukon, Alaska: U. S. Geol. Survey Bull. 218, p. 55, 1903.

[95] Idem, pp. 57–58.

described as interstratified with some beds of impure lignite. Tuff and lava, presumably of the same age, are exposed at several places between Hall Rapids and Anvik. The writer believes that these rocks are post-Cretaceous.

The Cretaceous rocks along the Yukon and on its tributaries between Anvik and Andreafski have been described by Harrington[96] as consisting of sandstone, argillite, and conglomerate. No detailed stratigraphic sections were measured, and only a few fossils were found. The rocks can not be certainly correlated with those exposed farther up the river, but the apparent absence of coal beds and of marine fossils, the presence of conglomerate, and the occurrence of the conglomerate in contact with pre-Cretaceous rocks suggest that most of the exposures represent the two lower divisions of the section between Melozi and Louden. Details concerning exposures at the several localities are given below.

The exposures on Anvik River include "mudstones or consolidated shales," fine-grained siliceous rocks that are locally cherty, and sandstone that is described as not so massive as those farther south. These sediments are interbedded at one locality, presumably near their top, with basaltic flows and tuff. No positive evidence as to the age of these rocks has been obtained, for they have yielded no fossils except indeterminate plant fragments. Harrington considered them presumably late Cretaceous or early Tertiary, although his map shows the sedimentary areas on Anvik River as Upper Cretaceous and the volcanic areas as Quaternary or late Tertiary. The writer suspects that none of the rocks on Anvik River described by Harrington are Cretaceous but that they are to be correlated with the Tertiary (?) volcanic and coal-bearing beds exposed along the Yukon at Hull Rapids and other localities.

The exposures near Holy Cross and opposite Paimut consist of conglomerate, grit, and sandstone with some thin beds of argillite. No fossils were obtained from these strata, but their lithologic character and their position apparently directly above the supposed Paleozoic greenstone indicate that they are to be correlated with the lower conglomeratic division of the Upper Cretaceous section between Melozi and Louden.

The exposures near Dogfish village and at other localities between Mountain Creek and Johnson Island consist chiefly of fine-grained rocks, including chert, quartzite, and shale, together with a few beds of grit and conglomerate. This area also adjoins a belt of pre-Cretaceous greenstone and therefore presumably includes basal beds equivalent to the Ungalik conglomerate. The presence of much

[96] Harrington, G. L., The Anvik-Andreafski region, Alaska: U. S. Geol. Survey Bull. 683, pp. 26–35, 1918.

fine-grained material suggests that the fresh-water shale and sandstone overlying the Ungalik conglomerate may also be represented. No fossils were obtained in this area.

The rocks exposed at Devils Elbow and elsewhere between Grand Island and Round Point include sandstone, argillite, and a variety of fine-grained siliceous and argillaceous sediments. The absence of conglomerate and the occurrence of most of these outcrops far away from the exposures of the pre-Cretaceous rocks suggest that these rocks are higher in the Cretaceous sequence than the Ungalik conglomerate. The apparent absence of marine strata or of coal beds suggests a correlation with the fresh-water shale and sandstone. The eastern margin of the area adjoins the pre-Cretaceous greenstone, and the equivalent of the Ungalik conglomerate may be present there. No such conglomerate has been described, however, and it may be that this contact is a fault.

The exposures near Marshall include sandstone, argillite, chert, and conglomerate, which crop out in close proximity to the pre-Cretaceous greenstone. These rocks are believed to represent the Ungalik conglomerate.

The rocks exposed on Chvilnuk River near Pilot Station and on Andreafski River include sandstone, argillite, and conglomerate. The presence of conglomerate suggests that the Ungalik conglomerate may be represented, but the absence of the pre-Cretaceous greenstone in or near this area indicates that the rocks may belong somewhat higher in the Cretaceous sequence. Some fresh-water invertebrate fossils collected on Andreafski River about 9 miles northeast of Andreafski indicate that the rocks at that locality probably belong in the upper coal-bearing division, but they may possibly represent the fresh-water shale and sandstone of the section between Melozi and Louden. Some fossil plants were obtained at the same locality, but they do not include species that are characteristic of any one subdivision of the Upper Cretaceous. Some marine fossils found near the mouth of Andreafski River indicate that one of the uppermost two divisions is represented there. The writer believes that all the fossil localities on Andreafski River belong in the upper coal-bearing division (Kaltag formation).

Age and correlation.—The Upper Cretaceous rocks of the lower Yukon are not known to be in contact with any formations other than the supposed Paleozoic rocks that underlie them and the supposed Tertiary volcanic beds that may overlie them. There is consequently no evidence as to the precise age of the Upper Cretaceous rocks, except that afforded by the fossils, which have been found in all four of the Upper Cretaceous formations.

The lower conglomeratic formation (Ungalik conglomerate) has yielded only some fragmentary plants and some indeterminate pelecypods, none of which give conclusive evidence as to the age. As these conglomeratic beds appear to underlie the other Upper Cretaceous rocks conformably, there is little if any doubt that they, too, are Upper Cretaceous.

The fresh-water shale and sandstone (Melozi formation) have yielded both fossil plants and fresh-water mollusks. The shells include chiefly some unidentified species of *Unio*, which afford no evidence as to the age of the rocks.

The marine sandstone and shale (Nulato formation) have yielded both fossil plants and marine invertebrates. Some fresh-water pelecypods (*Unio*) have been collected at one locality within the area of these rocks, but they were not obtained in place and are believed to have been derived from the underlying fresh-water shale and sandstone of the Melozi formation. Most of the marine invertebrates belong to unidentified species and have not been critically studied.[97] They indicate, according to Stanton,[98] "That the horizon is within the Upper Cretaceous but probably not higher than the middle of the Upper Cretaceous."

The coal-bearing rocks (Kaltag formation) contain abundant fossil plants, some fresh or brackish water mollusks, and probably a few marine mollusks. It is possible that all the marine fossils that have been listed as coming from these beds were derived from older rocks that have been erroneously correlated with these beds. These marine fossils represent only a few genera and apparently do not include any species that have not been recognized in the underlying marine sandstone and shale. The fresh or brackish water fossils include oysters and several genera of fresh-water mollusks that have not been recognized in the older fresh-water shale and sandstone.

The evidence yielded by the fossil plants, according to Hollick,[99] indicates with little doubt that the Upper Cretaceous flora of the Yukon as a whole is approximately of Dakota age. This conclusion is practically in accord with the evidence yielded by the marine invertebrates.

The Ungalik conglomerate has yielded only undetermined plant fragments and pelecypods. The fossils of the other divisions of the Upper Cretaceous on the lower Yukon are listed below.

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[97] After this paper was practically finished a critical study of the Upper Cretaceous invertebrate fossils of Alaska was undertaken by W. R. Smith. The results of that study have not yet been published, but preliminary lists of fossils identified by Smith have been used in making up the tables of fossils on pages 413–424.

[98] Stanton, T. W., unpublished statement.

[99] Personal communication.

Fossils from the Melozi formation [a]

	4782	2975	2976	4633	7715	1554	2963	3248	4634, 4783	3249	3250	3251	2922, 3251a	2675	2923
Asplenium foersteri Debey and Ettingshausen?							a								
"Pecopteris arctica Heer"?						b									
Aneimia, n. var							a								
Nilssonia, n. sp								a							
Podozamites lanceolatus (Lindley and Hutton) C. F. W. Braun								a							
Ginkgo digitata (Brongniart) Heer								a							
Ginkgo, n. sp				a				a							
Protophyllocladus polymorphus (Lesquereux) Berry							a								
Cephalotaxopsis, n. sp								a							
Cephalotaxopsis, n. var				a											
Cephalotaxopsis, n. sp				a											
Cephalotaxopsis, n. var								a							
Cephalotaxopsis, n. sp									a						
Tumion, n. sp				a				a							
Pinus?										a					
Sequoia cf. S. ambigua Heer		a													
Sequoia fastigiata (Sternberg) Heer										a					
Sequoia concinna Heer										a					
Sequoia reichenbachi (Geinitz) Heer								a							
Sequoia rigida Heer?												a			
Sequoia subulata Heer?									a						
Sequoia? (cones)								a		a					
Sphenolepsis			a												
Populus, n. sp										a					
Populites, n. sp							a		a	a					
Populites, n. sp							a		a						
Populites, n. sp										a					
Populites?, n. sp									a						
Populites, n. sp								a							
Myrica? trifoliata Newberry?										a					
Quercus eamesi Trelease?										a					
Ficus daphnogenoides (Heer) Berry										a	a				
MacClintockia, n. sp												a			
Aristolochia, n. sp							a				a				
Castaliites, n. sp															
Menispermites reniformis Dawson								a							
Menispermites, n. sp								a							
Menispermites, n. sp									a						
Magnolia amplifolia Heer											a				
Magnolia lacoeana Lesquereux											a				
Benzoin, n. var											a				
Daphnogene, n. sp									a						
Daphnophyllum dakotense Lesquereux?								a							
Cinnamomum, n. sp											a				
Platanus? newberryana Heer					a				a						
Platanus?, n. var									a						
Platanus latior (Lesquereux) Knowlton								a							
Platanus, n. var							a								
Platanus heerii Lesquereux					a				a						
Platanus			a										a		
Credneria, n. sp								a							
Credneria, n. sp								a							
Credneria, n. sp								a							
Credneria, n. sp								a							
Credneria, n. sp							a								
Pseudoprotophyllum, n. sp								a							
Pseudoprotophyllum, n. sp								a							
Pseudoprotophyllum, n. sp								a							
Pseudoaspidiophyllum, n. sp								a							
Pseudoaspidiophyllum, n. sp								a							
Cotinus, n. sp								a							
Sapindus morrisoni Lesquereux MS. Heer								a							
Sapindus apiculatus Velenovsky										a					
Paullinia, n. sp										a					
Vitis, n. sp							a								
Cissites, n. sp											a				
Cissites, n. sp								a							
Grewiopsis, n. sp								a							
Sterculia, n. sp							a								
Trails	d														
Ostrea															c
Unio, n. sp													c	c	c
Unio															d
Pelecypods									d						
Viviparus? or Campeloma?															d

[a] a, Identified by Arthur Hollick; b, identified by F. H. Knowlton; c, identified by W. R. Smith; d, identified by T. W. Stanton. The new species and new varieties of plants will be described in a monograph on the Upper Cretaceous flora of Alaska, by Arthur Hollick, now in preparation.

4782 (19). Yukon River, north bank, about 9 (?) miles below Melozi. Argillite associated with coarse conglomerate. W. W. Atwood, 1907.

2975 (2AC234). Yukon River, north bank, about 9 miles below Melozi. Thin bed of carbonaceous shale with "knife-edge" coal seams. A. J. Collier, 1902.

2976 (2AC235). Yukon River, north bank, about 10 miles below Melozi. Talus at foot of bluff. A. J. Collier, 1902.

4633 (18). Yukon River, north bank, about 10 miles below Melozi. Soft shale dipping into hillside. W. W. Atwood, 1907.

7715. Yukon River, north bank, 15 or 20 miles below the mouth of the Melozi. I. C. Russell, 1889.

1554 (9). "Below Melozikakat" [probably about 19 miles below Melozi River]. J. E. Spurr, 1896.

2963 (2AC236). Yukon River, north bank, 10 to 11 miles below Melozi. "Collected for about a mile along the foot of the cliff." A. J. Collier, 1902.

3248 (3AH11). Yukon River, north bank, about 12 miles below Melozi. Shaly sandstone about 300 feet above the river and talus on river bank. Arthur Hollick, 1903.

4634 (20), 4783 (21). Yukon River, north bank, about 12 miles below Melozi. Sandstone and shale. W. W. Atwood, 1907.

3249 (3AH12). Yukon River, north bank, about 12½ miles below Melozi. Talus on river bank. Arthur Hollick, 1903.

3250 (3AH13). Yukon River, north bank, about 13 miles below Melozi. Sandstone a short distance below small draw. Arthur Hollick, 1903.

3251 (3AH14). Yukon River, north bank, about 2 miles above Good Island, or 14 miles below Melozi. Talus. Arthur Hollick, 1903.

3251a (3AH14a). Yukon River, north bank, just above upper end of Good Island. Gray sandstone. Arthur Hollick, 1903.

2922 (3AH14a). Yukon River, north bank, just above upper end of Good Island. Gray sandstone. Same locality as 3251a. Arthur Hollick, 1903.

2675 (2AC237). Yukon River, north bank, behind Good Island. Sandstone pebbles at mouth of creek. A. J. Collier, 1902.

2923 (3AH14b). Yukon River, north bank, behind Good Island. Loose rock on river bank. Same locality as 2675. Arthur Hollick, 1903.

Fossils from the Nulato formation [a]

	2924	2676	2925	4784	2977, 2678	2926	2927, 3257	4637, 4785	4787	2677	3255	2928	2930	3256	2680	2929	2681	4788	4789	4790	4791	4792	2179, 7471	3264	2931	2982	3265	2983	3266	3267	4793
Fucus n. sp											a																				
Dryopteris oerstedi (Heer) Knowlton?																										a					
Nilssonia n. sp																													a		
Podozamites lanceolatus (Lindley and Hutton) C. F. W. Braun											a																		a		
Cephalotaxopsis, n. sp														a															a		
Cephalotaxopsis, n. var																								a							
Cephalotaxopsis																										a					
Sequoia ambigua Heer											a													a							
Sequoia reichenbachi (Geinitz) Herr								a																							
Sequoia sp.? (cones)																														a	
Castaliites, n. sp																											a				
Menispermites reniformis Dawson																							a								
Platanus heerii Lesquereux																							a								
Credneria, n. sp																													a		
Acer, n. sp																												a			
Cissites, n. sp														a																	
Hedera, n. sp																											a				
Viburnum, n. sp											a																				
Hemiaster																															d
Worm burrows					d	d						d																			
Nucula?, n. sp																			c												
Leda, n. sp										c																					
Cucullaea mathewsoni Gabb							c																								
Cucullaea truncata Gabb?					c																										
Cucullaea?								d																							
Pinna																															d
Inoceramus cf. I. labiatus Schlotheim			d							d		d										d									d
Ostrea, n. sp	c	c	c	c	c								c					c				c	c								c
Ostrea, n. sp		c								c												c									
Ostrea, n. sp							c																								
Ostrea sp		c		c					d						d																
Unio, n. sp	c																														
Trigonia leana Gabb			c		c		c						c				d	c				c	c								
Trigonia newcombei Packard?					c																										
Trigonia, n. sp					c																										
Trigonia		d																													
Anomia			d																			d	d								
Mytilus																							d								
Pleuromya, n. sp																															c

[a] a, Identified by Arthur Hollick; b, identified by F. H. Knowlton; c, identified by W. R. Smith; d, identified by T. W. Stanton.

Fossils from the Nulato formation—Continued

	2924	2676	2925	4784	2977, 2678	2926	2927, 3257	4637, 4785	4787	2677	3255	2928	2930	3256	2680	2929	2681	4788	4789	4790	4791	4792	2179, 7471	3264	2931	2982	3265	2983	3266	3267	4793
Pholadomya, n. sp													c		c	c															
Pholadomya																			d												
Thracia sp					c	c	c			c		c																			
Thracia?, n. sp					c	c	c																								
Thracia?																d															
Astarte, n. sp		c																													
Astarte							d																								
Astarte?, n. sp				d																											
Astarte?					c																										
Opis?																							d								
Venericardia							d																								
Lucina, n. sp					c	c	c					c											c								
Lucina?																															d
Cardium (Trachydium), n. sp										c			c		c	c		c	c		c	c	c								
Protocardia, n. sp																	c	c													
Protocardia, n. sp																							c								
Protocardia		d											d								d										
Veneridae					d				d			d					d														
Meretrix, n. sp		c																													c
Meretrix	d		d																			d			d						
Meretrix?																		d		d											
Tellina cf. T. ashburnerii Gabb															c																
Tellina?		d																													
Corbula																							d								
Panope, n. sp										c																					
Panope concentrica (Gabb) Whiteaves var				c					c											c											
Panopea					d		d	d	d			d										d									
Panopea?																			d												
Pelecypods			d																												
Viviparus, n. sp										c																					
Turritella																				d											
Actaeonella (Volvalina), n. sp																							c								
Actaeonella		d																													
Actaeonella?																									d						
Anchura cf. A. transversa Gabb							d																								
Sonneratia?					d	d	d																								
Ammonites					d																										
Crustacea (large Macruran)												d																			

2924 (3AH15). Yukon River, north bank, just above Fossil Bluff, about 5 miles above Louden. Rock fragments on beach. Arthur Hollick, 1903.

2676 (2AC238). Yukon River, north bank, at Fossil Bluff, 5 miles above Louden. Massive sandstone. A. J. Collier, 1902.

2925. (3AH15a). Yukon River, north bank, at Fossil Bluff, 5 miles above Louden. Sandstone and shale overlying "intrusive dike." Arthur Hollick, 1903.

4784 (23). Yukon River, north bank, 5 miles above Louden. Sandstone and shale overlying "intrusive lava." In place. Probably same locality as 2676 and 2925. W. W. Atwood, 1907.

2977, 2678 (2AC244). Yukon River, north bank at Bishop Mountain. A. J. Collier, 1902.

2926 (3AH17). Yukon River, north bank, at Bishop Rock. Crest of fold at upper end of exposure. Arthur Hollick, 1903.

2927, 3257 (3AH17a). Yukon River, north bank, at Bishop Rock. Talus at lower end of exposure. Arthur Hollick, 1903.

4785, 4637 (24). Yukon River, north bank, at Bishop Rock. W. W. Atwood, 1907.

4787 (27). Yukon River, north bank, near Pickart mine. Sandstone about 130 feet below the coal. (See section, p. 406.) W. W. Atwood, 1907.

2677 (2AC250). Yukon River, north bank. Strata below Pickart coal mine. A. J. Collier, 1902.

3255 (3AH18b). Yukon River, north bank, just below Pickart mine. Massive sandstone below the coal. Arthur Hollick, 1903.

2928 (3AH18c). Yukon River, north bank, a short distance below Pickart mine. Shale conformably beneath the sandstone that yielded lot 3255. Arthur Hollick, 1903.

2930 (3AH18d). Yukon River, north bank, for about 2 miles below 18c. Float. Arthur Hollick, 1903.

3256 (3AH18d). Yukon River, north bank. Sandstone just below 2930. Arthur Hollick, 1903.

2680 (2AC251). Yukon River, north bank, about 3 miles below Pickart mine. A. J. Collier, 1902.

2929 (3AH18e). Yukon River, north bank, opposite head of first island below Pickart mine. Sandstone. Arthur Hollick, 1903.

2681 (2AC252). Yukon River, north bank, 6 miles above Nulato. Massive sandstone. A. J. Collier, 1902.

4788 (28). Yukon River, north bank, 5½ miles below Pickart mine. Talus below sandstone cliff. W. W. Atwood, 1907.

4789 (29). Yukon River, north bank, 6 miles below Pickart mine. Sandstone near lens of coaly stringers. W. W. Atwood, 1907.

4790 (30). Yukon River, north bank, 6¼ miles below Pickart mine. W. W. Atwood, 1907.

4791 (31). Yukon River, north bank, 6½ miles below Pickart mine. W. W. Atwood, 1907.

4792 (32). Yukon River, north bank, 6¾ miles below Pickart mine. Sandstone above 4788 to 4791. W. W. Atwood, 1907.

2179, 7471 (358). Yukon River, north bank, between Pickart mine and Nulato. F. C. Schrader, 1899.

3264 (3AH25). Yukon River, west bank, at upper end of Bluff Point, 24 miles below Nulato. Sandstone and shale. Arthur Hollick, 1903.

2931 (3AH25a). Yukon River, west bank, at end of Bluff Point. Coarse sandstone. Arthur Hollick, 1903.

2982 (2AC263). Yukon River, west bank, 1 mile below Bluff Point. Sandstone. A. J. Collier, 1902.

3265 (3AH26). Yukon River, west bank, about 3 miles below Bluff Point. Shale. Arthur Hollick, 1903.

2983 (2AC264). Yukon River, west bank, about 4½ miles below Bluff Point. Massive sandstone. A. J. Collier, 1902.

3266 (3AH27). Yukon River, west bank, about 4½ miles below Bluff Point. Shale near 2983 (?). Arthur Hollick, 1903.

3267 (3AH28). Yukon River, west bank, 3 miles above Kaltag. Shale associated with thin bed of coal. Arthur Hollick, 1903.

4793 (34). Yukon River, west bank, 3 miles above Kaltag. Thick sandstone. W. W. Atwood, 1907.

Fossils from Kaltag formation [a]

	2962	4636	3252	4635	3253	2679, 2964	3254	4786	4638	2682	2AC—	2978	7122	3258	3260	2980	3259	3261	4639	2683, 2981	2932, 3262	3263	2984	4640	3268	2684	4642	4794	2685	3269	2933	4641	4795	2985	2986	3270	3271	4643	9774	7259, 9775	9776
Marchantia, n. sp.			a																																						
Asplenium foersteri Debey and Ettingshausen?	a		a	a																																					
Asplenium johnstrupi (Heer) Heer?	a		a																																						
Cladophlebis, n. sp.			a																																						
Onychiopsis nervosa (Fontaine) Berry	a																																								
Aneimia, n. var.																																a									
Stachypteris, n. sp.			a																																						
Sagenopteris variabilis (Velenovsky) Velenovsky																					a																				
Cycadites?																					a																				
Nilssonia, n. sp.			a																																						
Nilssonia, n. var.																	a		a																						
Nilssonia, n. sp.		a																																							
Nilssonia, n. sp.	a	a	a	a															a																						
Pterophyllum, n. sp.																																					a				
Podozamites lanceolatus (Lindley and Hutton) C. F. W. Braun	a	a	a	a													a	a	a																						
Ginkgo concinna Heer																	a		a																						
Ginkgo digitata (Brongniart) Heer	a																		a																						
Ginko laramiensis Ward?																					a																				
Ginkgo?				a																	a																				
Ginkgo, n. sp.																					a						a										a				
Ginkgo, n. sp.														a																a											
Ginkgo, n. sp.																											a														
Ginkgo, n. var.														a																											
Nageiopsis angustifolia Fontaine																	a																								
Protophyllocladus, n. sp.																														a											
Protophyllocladus subintegrifolius (Lesquereux) Berry																							a		a																
Protophyllocladus, n. sp.																							a																		
Cephalotaxopsis, n. sp.	a		a						a														a	a								a		a							
Cephalotaxopsis, n. var.		a	a																															a							
Cephalotaxopsis, n. var.				a																																					
Cephalotaxopsis																a							a											a							
Tumion, n. sp.	a		a	a		a											a				a																				

[a] a, Identified by Arthur Hollick; b, identified by F. H. Knowlton; c, identified by W. R. Smith; d, identified by T. W. Stanton.

Fossils from Kaltag formation—Continued

	2962	4636	3252	4635	3253	2679, 2964	3254	4786	4638	2682	2AC—	2978	7122	3258	3260	2980	3259	3261	4639	2683, 2981	2932, 3262	3263	2984	4640	3268	2684	4642	4794	2685	3269	2933	4641	4795	2985	2986	3270	3271	4643	9774	7259, 9775	9776
Sequoia fastigiata (Sternberg) Heer						a																																			
Sequoia concinna Heer									a								a		a																						
Sequoia, n. var																											a														
Sequoia				a								b								a																a					
Sequoia? (cones)							a										a		a		a																				
Sphenolepis sternbergiana (Dunker) Schenk			a																		?		a																		
Taxodium sp. Knowlton																																								b	
Glyptostrobus gronlandicus Heer				a					a												a																				
Glyptostrobus, n. sp																	a				a																				
Zinziberites, n. sp																																		a							
Piper, n. sp														a				a																							
Populites, n. sp									a																																
Populites, n. sp																											a														
Populites, n. sp	a																																								
Juglans arctica Heer				a					a																																
Betula, n. var																								a																	
Betulites, n. var																								a																	
Ficus, n. var			a																																						
Ficus melanophylla Lesquereux?			a																																						
Ficus, n. sp	a																																								
MacClintockia, n. sp														a																											
Paleonuphar, n. sp			a																																						
Castaliites, n. sp																																		a							
Castaliites, n. sp																																		a							
Castaliites																																		a							
Menispermites, n. sp																																a									
Menispermites, n. sp																			a																						
Liriodendropsis simplex (Newberry) Newberry																											a														
Asimina, n. sp														a																											
Laurus antecedens Lesquereux			a																								a														
Benzoin, n. var																						a				a															
Persea, n. sp	a																																								
Daphnogene, n. sp																			a																						
Platanus heerii Lesquereux																						a														a					
Platanus? newberryana Heer																	a																								
Platanus, n. sp					a																																				
Platanus, n. sp																									a																
Platanus, n. sp			a																																						

Platanus, n. sp									a					a																											
Platanus? sp	a																		a																						
Platanus?, n. sp	a		a																																						
Credneria, n. sp																									a																
Credneria, n. var													a																												
Credneria, n. sp														a																											
Credneria, n. sp			a				a																																		
Credneria, n. sp																									a																
Credneria, n. sp																			a																						
Paracredneria, n. sp					a																																				
Paracredneria, n. sp															a																										
Paracredneria?, n. sp																	a																								
Paracredneria? sp															a																										
Pseudoprotophyllum, n. sp			a																																						
Pseudoprotophyllum, n. sp																																a									
Pseudoprotophyllum, n. sp																			a								a			a											
Pseudoprotophyllum, n. sp						a																																			
Pseudoprotophyllum, n. sp							a						a						a																						
Pseudoprotophyllum, n. sp													a																												
Pseudoprotophyllum, n. sp			a										a				a								a																
Pseudoprotophyllum?, n. sp				a																																					
Pseudoprotophyllum																																		a							
Pseudoaspidiophyllum, n. sp															a																										
Leguminosites, n. sp	a		a																																						
Cassia, n. sp	a																																					a			
Acerites multiformis Lesquereux			a																																						
Rhamnites, n. sp							a																																		
Zizyphus, n. sp	a																																								
Vitis, n. sp														a																											
Vitis, n. sp				a																																					
Cissites, n. sp																														a											
Ampelopsis?, n. sp																																						a			
Tilia, n. sp																											a														
Sterculia, n. sp									a																																
Aralia wellingtoniana Lesquereux																																						a			
Aralia, n. sp																																						a			
Aralia polymorpha Newberry														a																											
Andromeda?																					a																				
Myrsine gaudini (Lesquereux) Berry			a																																						
Sapotacites, n. sp														a																											
Viburnum, n. sp					a																																				
Viburnum, n. sp	a																																								
Viburnum, n. sp																								a																	
Viburnum																							a																		
Phyllites, n. sp			a																																						
Phyllites			a																																						
Inoceramus?																																									d
Ostrea, n. sp						c																																			
Ostrea										c																d		d													d

Fossils from Kaltag formation—Continued

	2962	4736	3252	4635	3253	2679, 2964	3254	4786	4638	2682	2AC—	2978	7122	3258	3260	2980	3259	3261	4639	2683, 2981	2932, 3262	3263	2984	4640	3268	2684	4642	4794	2685	3269	2933	4641	4795	2985	2986	3270	3271	4643	9774	7259, 9775	9776
Unio, n. sp																													c		c										
Unio								d																									d						d	d	
Pecten, n. sp						c																																			
Thracia?											d																														
Corbicula?																			d	d																					
Sphaerium?																																								d	
Panopea																												d													
Viviparus, n. sp								c																																	
Viviparus (Tulotoma), n. sp								c																																	
Viviparus																			d	d									d		d		d								
Campeloma?																			d	d																					
Goniobasis																			d																					d	
Goniobasis?								d												d																					

2962 (2AC239). Yukon River, north bank, 4¾ miles above Louden. Hanging wall of coal bed about a quarter of a mile from the river and from the foot of a slide extending from the coal bed to the river. A. J. Collier, 1902.

4636 (22A). Yukon River, north bank, about 5 miles above Louden. Bedrock in place. W. W. Atwood, 1907.

3252 (3AH16). Yukon River, north bank, about 4¾ miles above Louden. Slide that came down from vicinity of coal mine. Arthur Hollick, 1903.

4635 (22). Yukon River, north bank, about 5 miles above Louden. Weathered material. Probably same as 2926 and 3252. W. W. Atwood, 1907.

3253 (3AH18). Yukon River, north bank, about 2 miles above Pickart mine. Sandstone. Arthur Hollick, 1903.

2679 (2AC249). Yukon River, north bank, strata above Pickart coal mine. A. J. Collier, 1902.

2964 (2AC249). Yukon River, north bank, 10 miles above Nulato. Strata above Pickart coal mine. A. J. Collier, 1902.

3254 (3AH18a). Yukon River, north bank, just above Pickart mine. Shale and sandstone overlying the coal. Arthur Hollick, 1903.

4786 (25). Yukon River, north bank, above Pickart mine. Sandstone about 665 feet above the coal horizon. (See section, p. 405.) W. W. Atwood, 1907

4638 (26). Yukon River, north bank, above Pickart mine. Shale and sandstone about 168 feet above the coal. (See section, p. 405.) W. W. Atwood, 1907.

2682 (2AC253). Yukon River, north bank, at Nulato. A. J. Collier, 1902.

—— (2AC—). "Front Street, Nulato." A. J. Collier, 1902.

2978 (2AC255). Yukon River, west bank, 6 miles below Nulato. Shale and thin-bedded sandstone. A. J. Collier, 1902.

7122. Yukon River, west bank, "about 7 miles below Nulato" (probably near Blatchford mine). W. H. Dall, 1866.

3258 (3AH19). Yukon River, west bank, at Blatchford coal mine, 9 miles below Nulato. Shale and sandstone underneath the coal. Arthur Hollick, 1903.

3260 (3AH21). Yukon River, west bank, 3 miles below Blatchford mine. Sandstone. Arthur Hollick, 1903.

2980 (2AC260). Yukon River, west bank, about 15 miles below Nulato, or 4½ miles below Blatchford mine. Landslide. A. J. Collier, 1902.

3259 (3AH20). Yukon River, west bank, 2 to 10 miles below Blatchford mine. Float along shore. Arthur Hollick, 1903.

3261 (3AG22). Yukon River, west bank, 6 miles below Blatchford mine. Shaly sandstone. Arthur Hollick, 1903.

4639 (33). Yukon River, west bank, 16 miles below Nulato. Shale and sandstone. Same locality as 3261. W. W. Atwood, 1907.

2683, 2981 (2AC262). Yukon River, west bank, about 20 miles below Nulato, or 3½ miles above Bluff Point, at foot of slide. A. J. Collier, 1902.

2932, 3262 (3AH23). Yukon River, west bank, about 20 miles below Nulato. Same as 2683. Arthur Hollick, 1903.

3263 (3AH24). Yukon River, west bank, about 22 miles below Nulato. Sandstone overlain and underlain by shale. Arthur Hollick, 1903.

2984 (2AC266). Yukon River, west bank, about 8 miles below Kaltag. A. J. Collier, 1902.

4640 (35). Yukon River, west bank, about 8 miles below Kaltag. Shale and sandstone. W. W. Atwood, 1907.

3268 (3AH29). Yukon River, west bank, about 8 miles below Kaltag. Sandstone and shale. Arthur Hollick, 1903.

2684 (2AC272). Yukon River, west bank, 18 or 20 miles below Kaltag. Loose pieces lying on dark shale. A. J. Collier, 1902.

4642 (36). Yukon River, west bank, 1½ miles above Williams coal mine. W. W. Atwood, 1907.

4794 (37). Yukon River, west bank, 1¼ miles above Williams mine. W. W. Atwood, 1907.

2685 (2AC282). Yukon River, west bank, 1 mile above Williams mine. Black shale. A. J. Collier, 1902.

3269 (3AH30). Yukon River, west bank, about 1 mile above Williams mine near 2685. Sandstone. Arthur Hollick, 1903.

2933 (3AH30). Yukon River, west bank, about 1 mile above Williams mine, a few yards below 3269. Arthur Hollick, 1903.

4641 (38), 4795 (39). Yukon River, west bank, 1 mile above Williams mine. W. W. Atwood, 1907.

2985 (2AC284). Yukon River, west bank, at Williams coal mine. "Fossils mostly taken from sandstone immediately above coal bed." A. J. Collier, 1902.

2986 (2AC289). Yukon River, west bank, just below "mine No. 1." Cross-bedded sandstone the base of which is 28 feet above the coal. A. J. Collier, 1902.

3270 (3AH31). Yukon River, west bank, near "mine No. 1." Shale. Arthur Hollick, 1903.

3271 (3AH32). Yukon River, west bank, about 18 miles below mine No. 1. Float at outcrop of sandstone and shale with thin coal bed. Arthur Hollick, 1903.

4643 (40). Yukon River, west bank, about 18 miles below mine No. 1. W. W. Atwood, 1907.

9774 (16AHa134). Andreafski River, east bank, 9 miles northeast of Andreafski. G. L. Harrington, 1916.

7259 (16AHa136), 9775 (16AHa135). Andreafski River, east bank, 9⅕ miles northeast of Andreafski. G. L. Harrington, 1916.

9776 (16AHa140). Andreafski River, west bank, 1½ miles below Andreafski. G. L. Harrington, 1916.

The foregoing lists show that a relatively large proportion of the ferns and gymnosperms range throughout two or more of the formations, but that most of the angiosperms are restricted to one formation. This difference evidently means that the angiosperms, being morely highly organized, were more sensitive to changes in environment and consequently are better horizon markers. It is shown statistically by the fact that, among the angiosperms, 80 per cent of those in the fresh-water shale and sandstone, 37½ per cent of those in the marine sandstone and shale, and 86 per cent of those in the coal-bearing rocks are characteristic of one formation, whereas among the gymnosperms and lower plants only 24 per cent of those in the fresh-water shale and sandstone, 33 per cent of those in the marine sandstone and shale, and 56 per cent of those in the coal-bearing rocks are characteristic of one formation.

A similar difference between the angiosperms and the lower plants is shown in the stratigraphic range of those species that occur in other regions. Although most of the species of fossil plants from

these beds that are known in other regions occur in the Dakota sandstone or in beds that have been correlated with it, there are about a dozen species which have been generally regarded as characteristic of the Lower Cretaceous, as well as a few species that have been regarded as Montana or possibly Laramie. Every one of these supposed Lower Cretaceous and late Upper Cretaceous species are among the gymnosperms or lower plants, whereas all the previously described species of angiosperms that have been found in the Upper Cretaceous rocks of this region are known elsewhere only in the Dakota sandstone or in rocks of approximately equivalent age.

Stratigraphic range of Upper Cretaceous fossils from the lower Yukon

	Range on lower Yukon				Range in other regions
	Ungalik	Melozi	Nulato	Kaltag	
Fucus n. sp.			×		
Marchantia n. sp.				×	
Dryopteris oerstedi (Heer) Knowlton?			×		Lower Cretaceous.
Asplenium foersteri Debey and Ettingshausen?		×		×	Raritan, lower Atane.
Asplenium johnstrupi (Heer) Heer?				×	Lower Cretaceous.
Cladophlebis n. sp.				×	
Onychiopsis nervosa (Fontaine) Berry				×	Lower Cretaceous.
"Pecopteris arctica Heer"?		×			
Aneimia n. var.		×		×	
Stachypteris n. sp.				×	
Sagenopteris variabilis (Velenovsky) Velenovsky				×	Magothy.
Cycadites?				×	
Nilssonia n. sp.		×		×	
Nilssonia n. var.				×	
Nilssonia n. sp.				×	
Nilssonia n. sp.			×	×	
Pterophyllum n. sp.				×	
Podozamites lanceolatus (Lindley and Hutton) C. F. W. Braun		×	×	×	Dakota?
Ginkgo concinna Heer				×	Lower Cretaceous.
Ginkgo digitata (Brongniart) Heer		×		×	Lower Cretaceous.
Ginkgo laramiensis Ward?				×	Laramie, Nanaimo, etc.
Ginkgo?				×	
Ginkgo n. sp.				×	
Ginkgo n. sp.				×	
Ginkgo n. sp.		×		×	
Ginkgo n. var.				×	
Nageiopsis angustifolia Fontaine				×	Lower Cretaceous.
Protophyllocladus n. sp.				×	
Protophyllocladus polymorphus (Lesquereux) Berry		×			Laramie.
Protophyllocladus subintegrifolius (Lesquereux) Berry				×	Dakota.
Protophyllocladus n. sp.				×	
Cephalotaxopsis n. sp.		×	×	×	
Cephalotaxopsis n. var.		×	×	×	
Cephalotaxopsis n. sp.		×			
Cephalotaxopsis n. var.		×		×	
Cephalotaxopsis n. sp.		×			
Cephalotaxopsis			×	×	
Tumion n. sp.		×		×	
Pinus?		×			
Sequoia ambigua Heer		×	×		Magothy, Kome, etc.
Sequoia fastigiata (Sternberg) Heer		×		×	Dakota.
Sequoia concinna Heer		×		×	Magothy, Patoot.
Sequoia reichenbachi (Geinitz) Heer		×	×		Dakota.
Sequoia rigida Heer?		×			Lower Cretaceous.
Sequoia, n. var.				×	
Sequoia subulata Heer?		×			Lower Cretaceous.
Sequoia				×	
Sequoia? (Cones)		×	×	×	
Sphenolepsis sternbergiana (Dunker) Schenk				×	Lower Cretaceous.
Sphenolepsis		×			
Taxodium sp. Knowlton				×	
Glyptostrobus grönlandicus Heer				×	Lower Cretaceous.
Glyptostrobus, n. sp.				×	
Zingiberites, n. sp.				×	
Piper, n. sp.				×	

Stratigraphic range of Upper Cretaceous fossils from the lower Yukon—Contd.

	Range on lower Yukon				Range in other regions
	Ungalik	Melozi	Nulato	Kaltag	
Populus, n. sp	----	×	----	----	
Populites, n. sp	----	----	----	×	
Populites, n. sp	----	----	----	×	
Populites, n. sp	----	×	----	×	
Populites, n. sp	----	×	----	----	
Populites, n. sp	----	×	----	----	
Populites? n. sp	----	×	----	----	
Populites, n. sp	----	×	----	----	
Myrica? trifoliata Newberry?	----	×	----	----	Dakota.
Juglans arctica Heer	----	----	----	×	Dakota.
Betula, n. var	----	----	----	×	
Betulites, n. var	----	----	----	×	
Quercus eamesi Trelease?	----	×	----	----	Dakota.
Ficus, n. var	----	----	----	×	
Ficus daphnogenoides (Heer) Berry	----	×	----	----	Dakota.
Ficus melanophylla Lesquereux?	----	----	----	×	Dakota.
Ficus, n. sp	----	----	----	×	
MacClintockia, n. sp	----	----	----	×	
MacClintockia, n. sp	----	×	----	----	
Aristolochia, n. sp	----	×	----	----	
Paleonuphar, n. sp	----	----	----	×	
Castaliites, n. sp	----	×	----	----	
Castaliites, n. sp	----	----	×	----	
Castaliites, n. sp	----	----	----	×	
Castaliites, n. sp	----	----	----	×	
Castaliites	----	----	----	×	
Menispermites reniformis Dawson	----	×	×	----	?British Columbia.
Menispermites, n. sp	----	×	----	----	
Menispermites, n. sp	----	×	----	----	
Menispermites, n. sp	----	----	----	×	
Menispermites, n. sp	----	----	----	×	
Magnolia amplifolia Heer	----	×	----	----	Dakota.
Magnolia lacoeana Lesquereux	----	×	----	----	Dakota.
Liriodendropsis simplex (Newberry) Newberry	----	----	----	×	Raritan, Magothy.
Asimina, n. sp	----	----	----	×	
Laurus antecedens Lesquereux	----	----	----	×	Dakota.
Benzoin, n. var	----	×	----	×	
Persea, n. sp	----	----	----	×	
Daphnogene, n. sp	----	×	----	----	
Daphnogene, n. sp	----	----	----	×	
Daphnophyllum dakotense Lesquereux?	----	×	----	----	Dakota.
Cinnamomum, n. sp	----	×	----	----	
Platanus? newberryana Heer	----	×	----	×	Dakota.
Platanus? n. var	----	×	----	----	
Platanus, n. sp	----	----	----	×	
Platanus latior (Lesquereux) Knowlton	----	×	----	----	Dakota.
Platanus n. var	----	×	----	----	
Platanus n. sp	----	----	----	×	
Platanus heerii Lesquereux	----	×	×	×	Dakota.
Platanus n. sp	----	----	----	×	
Platanus n. sp	----	----	----	×	
Platanus	----	×	----	----	
Platanus? sp	----	----	----	×	
P atanus? n. sp	----	----	----	×	
Credneria n. sp	----	×	----	×	
Credneria n. var	----	----	----	×	
Credneria n. sp	----	----	----	×	
Credneria n. sp	----	×	----	----	
Credneria n. sp	----	----	----	×	
Credneria n. sp	----	×	×	----	
Credneria n. sp	----	----	----	×	
Credneria n. sp	----	×	----	----	
Credneria n. sp	----	×	----	----	
Credneria n. sp	----	----	----	×	
Paracredneria n. sp	----	----	----	×	
Paracredneria n. sp	----	----	----	×	
Paracredneria? n. sp	----	----	----	×	
Paracredneria? sp	----	----	----	×	
Pseudoprotophyllum n. sp	----	----	----	×	
Pseudoprotophyllum n. sp	----	----	----	×	
Pseudoprotophyllum n. sp	----	×	----	----	
Pseudoprotophyllum n. sp	----	----	----	×	
Pseudoprotophyllum n. sp	----	----	----	×	
Pseudoprotophyllum	----	×	----	×	
Pseudoprotophyllum n. sp	----	----	----	×	
Pseudoprotophyllum n. sp	----	×	----	×	

Stratigraphic range of Upper Cretaceous fossils from the lower Yukon—Contd.

	Range on lower Yukon				Range in other regions
	Ungalik	Melozi	Nulato	Kaltag	
Pseudoprotophyllum? n. sp				×	
Pseudoprotophyllum				×	
Pseudoaspidiophyllum n. sp		×			
Pseudoaspidiophyllum n. sp		×			
Pseudoaspidiophyllum n. sp				×	
Leguminosites n. sp				×	
Cassia n. sp				×	
Cotinus n. sp		×			
Acer n. sp			×		
Acerites multiformis Lesquereux				×	Dakota.
Sapindus morrisoni Lesquereux MS. Heer		×			Dakota.
Sapindus apiculatus Velenovsky		×			Magothy?
Paullinia n. sp		×			
Rhamnites n. sp				×	
Zizyphus n. sp				×	
Vitis n. sp				×	
Vitis n. sp				×	
Vitis n. sp		×			
Cissites n. sp				×	
Cissites n. sp		×	×		
Cissites n. sp		×			
Ampelopsis? n. sp				×	
Tilia n. sp				×	
Grewiopsis n. sp		×			
Sterculia n. sp				×	
Aralia wellingtoniana Lesquereux				×	Dakota.
Aralia, n. sp				×	
Aralia polymorpha Newberry				×	Raritan
Hedera n. sp		×			
Andromeda?				×	
Myrsine gaudini (Lesquereux) Berry				×	Dakota, Magothy.
Sapotacites n. sp				×	
Viburnum, n. sp			×	×	
Viburnum n. sp				×	
Viburnum n. sp				×	
Viburnum				×	
Phyllites n. sp				×	
Phyllites				×	
Undetermined plant fragments	×				
Hemiaster			×		
Worm burrows			×		
Trails		×			
Nucula? n. sp			×		
Nucula?			×		
Leda n. sp			×		
Cucullaea mathewsoni Gabb			×		Eocene (Martinez formation).
Cucullaea truncata Gabb?			×		Chico.
Cucullaea			×		
Cucullaea?			×		
Pinna			×		
Inoceramus cf. I. labiatus Schlotheim			×		Chico, Colorado group.
Inoceramus			×		
Inoceramus?				×	
Ostrea n. sp			×		
Ostrea n. sp			×	×	
Ostrea n. sp			×		
Ostrea		×	×	×	
Unio n. sp		×		×	
Unio n. sp			×		
Unio		×		×	
Trigonia leana Gabb			×		Chico.
Trigonia newcombei Packard?			×		Haida formation.
Trigonia n. sp			×		
Trigonia			×		
Pecten n. sp				×	
Anomia			×		
Mytilus			×		
Pleuromya n. sp			×		
Pholadomya n. sp			×		
Pholadomya			×		
Thracia sp			×	×	
Thracia? n. sp			×		
Thracia?			×		
Astarte n. sp			×		

Stratigraphic range of Upper Cretaceous fossils from the lower Yukon—Contd.

	Range on Lower Yukon				Range in other regions
	Ungalik	Melozi	Nulato	Kaltag	
Astarte			×		
Astarte? n. sp			×		
Astarte?			×		
Opis?			×		
Corbicula?				×	
Sphaerium?				×	
Venericardia			×		
Meekia?			×		
Lucina n. sp			×		
Lucina?			×		
Cardium (Trachydium) n. sp			×		
Protocardia n. sp			×		
Protocardia n. sp			×		
Protocardia			×		
Veneridae			×		
Meretrix n. sp			×		
Meretrix			×		
Meretrix?			×		
Tellina cf. T. ashburnerii Gabb			×		Chico.
Tellina?			×		
Corbula			×		
Panope n. sp			×		
Panope concentrica (Gabb) Whiteaves var			×		Chico.
Panopea			×	×	
Panopea?			×		
Pelecypods	×	×	×		
Viviparus n. sp			×	×	
Viviparus (Tulotoma) n. sp				×	
Viviparus				×	
Viviparus? or Campeloma?		×			
Campeloma?				×	
Turritella			×		
Goniobasis				×	
Goniobasis?				×	
Actaeonella (Volvulina) n. sp			×		
Actaeonella			×		
Actaeonella?			×		
Anchura cf. A. transversa Gabb			×		Chico.
Sonneratia?			×		
Ammonites			×		
Crustacea (large macruran)			×		

In conclusion it may be stated that the Upper Cretaceous rocks of the lower Yukon region seem to correspond in age, in a general way, with the Dakota sandstone. The evidence of the plants and of the marine mollusks is practically in accord, most of the previously described species of plants occurring in the Dakota sandstone and the marine mollusks indicating "that the horizon is within the Upper Cretaceous but probably not higher than the middle of the Upper Cretaceous." The writer believes, however, that these rocks probably have a considerably greater range in age than the Dakota sandstone. This is indicated by the thickness of the rocks, which probably exceeds 8,000 feet; by their divisibility into four distinct formations; and by the fact that a large proportion of the plants, including almost all the angiosperms, do not range up from one of the formations into another. If it were possible to make a comparison of the floras with modern lists of fossil plants occurring at suc-

cessive horizons throughout the Upper Cretaceous of a near-by region, the comparison would probably indicate that a considerable part, very likely the lower half or two-thirds of the Upper Cretaceous is represented by the Upper Cretaceous rocks of the lower Yukon.

INNOKO AND IDITAROD VALLEYS

GENERAL FEATURES

The Upper Cretaceous rocks of the Innoko and Iditarod Valleys, which are probably the southern extension of the Upper Cretaceous rocks of the lower Yukon region, consist chiefly of marine shale and sandstone. Some terrestrial (coal-bearing) sandstone which is closely associated with them may be intercalated Upper Cretaceous deposits or may be infolded Tertiary sediments. These Upper Cretaceous strata are believed to rest everywhere upon Paleozoic rocks, no Lower Cretaceous or earlier Mesozoic rocks being known in this region, unless some chert and argillite exposed along the divide between the Innoko and the South Fork of the Sulatna, which Mertie and Harrington [1] referred tentatively to the Mesozoic, should prove definitely to be of Mesozoic age. The chert and argillite beds in the writer's opinion, are certainly pre-Cretaceous. The thickness of the Upper Cretaceous rocks is not known but is believed to be several thousand feet. They may be overlain unconformably by the supposed Tertiary conglomerate, grit, and sandstone of the upper Susulatna Valley (see pp. 431–432), by the possibly Tertiary coal-bearing sandstone [2] on Poorman Creek and near Iditarod, and by the supposed Tertiary lignite-bearing beds [3] on the lower Innoko.

UPPER CRETACEOUS

SHALE AND SANDSTONE

Historical review.—The Upper Cretaceous shale and sandstone of this district were first mentioned by Maddren, who made a hurried geologic reconnaissance of the Innoko placer district in 1908. Maddren described,[4] under the heading "Mesozoic rocks in the Innoko basin," some "hard limy sandstones and shales" exposed near the point where the Innoko leaves the mountains; and also conglomerate, grit, and shale exposed south of Ganes Creek. Maddren found no local evidence as to the age of these rocks, except that they unconformably overlie rocks which he believed to be Devonian and

[1] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 22–24, 1924.
[2] Idem, pp. 26–27, 34, 119–120.
[3] Maddren, A. G., The Innoko gold-placer district, Alaska: U. S. Geol. Survey Bull. 410, pp. 56–57, 1910.
[4] Idem, p. 55.

that they are more indurated than some beds farther down the Innoko which he supposed were Tertiary. His conclusion as to their age is that they "are considered to be of Mesozoic age and to be northeasterly outliers of the extensive Mesozoic formations found by Spurr on Kuskokwim River."

Maddren also described[5] black slate exposed on Innoko River from a point 10 miles below Ophir to the divide south of Ganes Creek, which he regarded as unconformably underlying the "Mesozoic rocks in the Innoko basin" and as Devonian or Silurian, but which subsequent writers have considered Mesozoic.

In 1910 Maddren again visited the Innoko-Iditarod district, but the geologic results of this field examination have been published only in a preliminary statement,[6] in which it is said that

> The sedimentary rocks of the Kuskokwim Mountains are a series of alternating beds of sandstones, carbonaceous and calcareous shales, shaly and siliceous limestones, granitic arkoses, volcanic tuffs, and conglomerates. The sandstones are generally rather thinly bedded and flaggy. The shales range from soft to fairly hard rocks and in the Innoko district appear to be partly altered to slates. Near their contacts with granitic intrusives they have been locally hardened into blocky quartzites and argillites.
>
> The few fragmentary fossil remains of land plants and marine-shell forms that have so far been found in these sediments point to an undoubted Mesozoic age for the series and a probable Cretaceous age for its younger members, of which the arkose sandstones appear to form a part.

Another geologic reconnaissance of the Innoko-Iditarod district was made in 1912 by Eakin,[7] who gave a general description of the distribution and character of the Cretaceous rocks. The Cretaceous rocks are described as chiefly sedimentary, but with some basic flows, breccia, and tuff irregularly distributed among them. The sedimentary rocks comprise coarse and fine conglomerate, sandstone, shale, and slate. The conglomerate is found chiefly near the base of the series, in proximity to the old metamorphic rocks from which it was derived. By far the larger part of the sedimentary series is composed of sandstone and shale or slate. Marine Upper Cretaceous fossils, collected on Ophir Creek, are mentioned but not listed.

A geologic reconnaissance from Lake Clark to Iditarod was made by P. S. Smith in 1914. Although the area described and mapped by Smith lies south of the Innoko-Iditarod district, some of the rocks which he describes, namely, the "Mesozoic sedimentary rocks north and west of the Holitna,"[8] were traced from the Kuskokwim to

[5] Maddren, A. G., op. cit., pp. 49–50.

[6] Maddren, A. G., Gold placer mining developments in the Innoko-Iditarod region: U. S. Geol. Survey Bull. 480, pp. 243–245, 1911.

[7] Eakin, H. M., The Iditarod-Ruby region, Alaska: U. S. Geol. Survey Bull. 578, pp. 23–24, pl. 3, 1914.

[8] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 77–84, 1917.

Iditarod, and exposures near Iditarod undoubtedly were in part the basis of the description, though they are not specifically mentioned. In discussing the age and correlation of these rocks, Smith quotes a previously unpublished statement by Stanton[9] on some Upper Cretaceous fossils collected by Eakin in the Innoko district in 1912.

The geology of the Innoko-Iditarod district was studied by Mertie in 1915, and a preliminary report on this work contains a brief general description of the Cretaceous rocks.[10]

The Tolstoi placer mining district was visited in 1917 by G. L. Harrington, who has given a brief general description of the Cretaceous rocks.[11]

The final report on the Ruby-Kuskokwim region by Mertie and Harrington contains a full description of the Upper Cretaceous beds under the heading "Upper Cretaceous and Eocene rocks." This account[12] contains a general discussion of the distribution, lithology, stratigraphy, structure, fauna, flora, and age of the Upper Cretaceous and Tertiary rocks of the entire region, of which the area occupied by Upper Cretaceous rocks not only includes parts of the Innoko and Iditarod valleys but extends southward to the Kuskowim. Local details concerning the rocks in several geographic subdivisions of the region are given under separate headings. Lists of fossils as identified by Stanton are quoted. The supposed Tertiary rocks were not mapped separately from the Upper Cretaceous rocks in the field, but the separation is indicated in a general way in the text.[13] Most of the description is believed to apply to the Upper Cretaceous rocks. The fossils listed[14] in lots 9364, 9365, 9366, and 7007 are believed to be Tertiary.

Stratigraphic description.—The Upper Cretaceous rocks of the Innoko and Iditarod valleys consist chiefly of shale and sandstone, with some intraformational conglomerate. Their thickness is not known, but according to Mertie and Harrington it is to be measured in thousands of feet. Their base has not been recognized, but they are believed to lie unconformably upon Mesozoic (?) chert and argillite and Paleozoic rocks. They are overlain, with probable unconformity, in the writer's opinion, by conglomerate, grit, and sandstone that are exposed in the upper Susulatna Valley and contain fossil plants,[14] which Hollick believes to be Tertiary, together

[9] Smith, P. S., op. cit., p. 83.

[10] Mertie, J. B., jr., and Harrington, G. L., Mineral resources of the Ruby-Kuskokwim region: U. S. Geol. Survey Bull. 642, p. 233, 1916.

[11] Harrington, G. L., The gold and platinum placers of the Tolstoi district: U. S. Geol. Survey Bull. 692, p. 344, 1919.

[12] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 24–41, pls. 3, 4, 1924.

[13] Idem, p. 30.

[14] Idem, p. 40.

with fossil shells which Stanton says "probably not lower than Upper Cretaceous." The coal-bearing sandstone found in and near the Upper Cretaceous areas near Iditarod and at other places may be a member of the Upper Cretaceous sequence or may be infolded Tertiary beds. These coal-bearing beds have yielded no fossils.

Age and correlation.—The Upper Cretaceous shale and sandstone of the Innoko and Iditarod valleys have yielded fresh-water and marine fossils, concerning which Stanton[16] has submitted the following statements:

7822 (12 AE 2). Ridge north of Folger Creek, 21 miles from margin of flats. Collected by H. M. Eakin in 1912. *Unio* sp. Casts of a very small undescribed species. Specimens of a small *Unio*, possibly belonging to this species and in closely similar rock, were collected by Collier at Good Island, on the Yukon above the mouth of the Koyukuk. The fossils give no direct information as to the age, as similar types occur in both Cretaceous and Tertiary, but from geographic relations the locality at Good Island ought to be near the base of the Upper Cretaceous.

7823 (12 AE 3). Ophir Creek 1 mile above town. Float in creek bed. Collected by H. M. Eakin in 1912. *Inoceramus* sp. Several fragmentary distorted specimens that may belong to *Inoceramus digitatus* Sowerby, an Upper Cretaceous species. Whether it is really this species or not, it is believed to be an Upper Cretaceous type.

9367 (4). 1.1 miles from southwest peak of Camelback Mountain and 1.3 miles from northeast peak at head of Bonanza Creek. Collected by J. B. Mertie, jr., in 1915. *Inoceramus* sp. related to *I. labiatus* Schlotheim. Probably Upper Cretaceous.

KUSKOKWIM REGION

GENERAL FEATURES

The Cretaceous rocks of the Kuskokwim region include marine Lower Cretaceous sandstone and conglomerate on the western front of the Oklune Mountains, east of Kuskokwim Bay, and fresh-water and marine Upper Cretaceous shale, sandstone, and conglomerate exposed along Kuskokwim River and its tributaries. The Lower Cretaceous rocks are known only from float material at a single locality and are not believed to have any great areal extent, although they may be present in much of the unmapped area south of Kuskokwim River. The Upper Cretaceous rocks are the direct southern extension of the Upper Cretaceous rocks of the Iditarod-Innoko district and are believed to extend throughout broad areas on both sides of the Kuskokwim.

The lower Cretaceous rocks of the Kuskokwim region consist of sandstone and conglomerate and probably shale. Their thickness and stratigraphic sequence have not been determined. The fauna as

[16] Stanton, T. W., cited by Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 39, 40, 1924.

now known includes only *Aucella crassicollis*, which is the characteristic fossil of the Lower Cretaceous of Alaska. These rocks are believed to rest unconformably on late Carboniferous or early Mesozoic volcanic rocks and are probably overlain unconformably by the Upper Cretaceous rocks described below.

The Upper Cretaceous rocks of the Kuskokwim region consist of conglomerate, sandstone, and shale having a thickness of many thousand feet. It is believed that in the lower Kuskokwim region they rest unconformably on the Lower Cretaceous sandstone and conglomerate. Farther up the river, where the Lower Cretaceous rocks are absent, the Upper Cretaceous rocks lie unconformably on Devonian limestone. The Upper Cretaceous rocks include both marine and nonmarine members, which are believed to be the equivalents and perhaps the continuous southward extensions of some or all of the Upper Cretaceous formations exposed on the lower Yukon.

LOWER CRETACEOUS

Historical review.—The Lower Cretaceous rocks of the Kuskokwim region were included by Spurr[17] in the "Oklune series," which he defined as including the larger part of the consolidated sedimentary rocks between Kuskokwim and Nushagak bays. This area includes rocks of diverse character, which probably do not constitute a stratigraphic unit. The only evidence that any of them are Lower Cretaceous was found in a boulder of sandstone and conglomerate, containing *Aucella crassicollis*, which Spurr obtained on Kanektok River near the western front of the "Oklune" (Ahklun) Mountains. Spurr believed that this boulder "undoubtedly came from rocks in the immediate vicinity," which he described as "sandstones, arkoses, conglomerates, and carbonaceous shales." These rocks lie on the edge of the area occupied by the "Oklune series," which Spurr defined as including shale, limestone, chert, arkose, lava, and tuff. His description includes a detailed account of the lithology and structure of the rocks observed at several localities and general statements concerning the character, age, and correlation. A statement by T. W. Stanton concerning the fossils from Kanektok River is repeated.

A brief discussion of the age and relations of the "Oklune series" was given by Brooks,[18] who referred it to the "Jura-Cretaceous," but no new information was presented.

The southwestern extension of the "Oklune series" in the Goodnews Bay district was mapped by Harrington as "Mesozoic (?)

[17] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 133–134, 163–169, 181–182, 1900.

[18] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 236, 1906.

sandstones, slates, argillites, cherts, and graywackes, with some included flows and tuffs of basalt." Harrington's description[19] of these rocks is very brief and does not clearly indicate the distinction between the supposed Mesozoic and the supposed Carboniferous rocks, which are separated on the map.[20] Harrington obtained no fossils and gives no stratigraphic details or any evidence of the age of the rocks.

Stratigraphic description.—The "Oklune series" was defined by Spurr as follows:[21]

> Lithologically the series consists of beds which are in a general way similar throughout, being shales, impure limestones, and cherts, often organic, with beds of arkose, derived from granites or other coarse-grained igneous rocks. In nearly every district are abundant volcanic rocks, of ancient appearance, having a greenish color due to alteration, and associated with these are sedimentary tuffs, which are evidently derived from the same volcanic sources. Volcanic material is more abundant in certain districts than in others but is thoroughly characteristic of the series.

Age and correlation.—The only fossils that have been obtained from the rocks referred to the "Oklune series" are some specimens of *Aucella crassicollis* which Spurr obtained in a large boulder of sandstone and conglomerate on Kanektok River just below Nukluk Creek and which he believed came from the near-by beds of arkose, sandstone, conglomerate, and carbonaceous shale. The position of these beds in the "Oklune series," the general stratigraphic sequence and thickness of the "Oklune series," and the identity of the rocks that underlie and overlie it have not been determined.

The writer believes that the "Oklune series" as defined by Spurr constitutes a heterogeneous assemblage of rocks having a wide stratigraphic range. The volcanic members are probably not Cretaceous and may perhaps be correlated in part with the late Carboniferous or early Mesozoic tuff that overlies an upper Carboniferous limestone on the Kuskokwim just above Ohagamut and in part with the Tertiary volcanic rocks of the lower Yukon and Bristol Bay districts. The identity of part of them with the late Carboniferous or early Mesozoic volcanic rocks is suggested by the fact that in the southwestern extension of this area, near Goodnews Bay, Harrington found a limestone which he considered as possibly Carboniferous. The "Oklune series" may also include the equivalent of part of the Upper Cretaceous shale and sandstone that cross the Kuskokwim above Kolmakof. Possibly only a small part of the rocks that were included in the "Oklune series" is Lower Cretaceous.

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19 Harrington, G. L., Mineral resources of the Goodnews Bay region, Alaska: U. S. Geol. Survey Bull. 714, pp. 215–218, 1921.

20 Idem, pl. 7.

21 Spurr, J. E., op. cit., p. 168.

It may be concluded that there are Lower Cretaceous *Aucella*-bearing rocks in the lower Kuskokwim region which include sandstone and conglomerate and probably shale. The thickness and stratigraphic sequence of these rocks are not known. They probably lie unconformably upon late Carboniferous or early Mesozoic volcanic rocks and are probably overlain unconformably by Upper Cretaceous conglomerate, sandstone, and shale.

UPPER CRETACEOUS

Historical review.—The Upper Cretaceous rocks of the Kuskokwim region were described[22] by Spurr as the "Holiknuk series." Spurr also described[23] some supposed Cretaceous rocks as the "Kolmakof series," which he regarded as the probable lateral equivalent of the "Holiknuk series" but as differing from it in being composed largely of volcanic material. The writer believes, as will be shown below (see p. 440), that probably only part of the "Kolmakof series" is Cretaceous. Spurr's descriptions of the "Holiknuk" and "Kolmakof series" include detailed statements concerning the rocks observed at several exposures and general discussions of the distribution, composition, structure, and age of the series. A statement by T. W. Stanton concerning fossils from the "Holiknuk series" is quoted.

In a brief discussion of the Mesozoic rocks of the Kuskokwim Valley, Brooks[24] suggests that the "Holiknuk series" may belong to the Jurassic or Triassic and that the "Kolmakof series" and "Oklune series" may be younger.

The quicksilver deposits on Kuskokwim River 15 miles above Georgetown and 5 miles below Kolmakof were visited in 1914 by P. S. Smith and A. G. Maddren,[25] whose report contains some observations concerning the Cretaceous rocks in the vicinity. The rocks at the Parks prospect, 15 miles above Georgetown, which had been included by Spurr in the "Holiknuk series," were described by Smith and Maddren as Cretaceous sandstone and shale cut by dikes and sills. The rocks at the prospect 5 miles below Kolmakof, which had been included by Spurr in the "Kolmakof series," were described by Smith and Maddren as sandstone and shale aggregating at least 4,000 to 5,000 feet in thickness and cut by dikes and sills. It should be noted that although Spurr described the "Kolmakof

[22] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 125–128, 159–161, 182, 1900.

[23] Idem, pp. 129–131, 161–163, 182–183.

[24] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, p. 236, 1906.

[25] Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region: U. S. Geol. Survey Bull. 622, pp. 275–278, 281–286, 1915.

series" as dominantly volcanic, a critical study of his detailed observations shows that the rocks for about 14 miles below Kolmakof are shale and sandstone, like those of the "Holiknuk series," cut by dikes and sills and without true volcanic members, and that the undoubtedly volcanic members of the series were found farther down the river, where they are not associated with any supposed Cretaceous shale and sandstone, but where Maddren subsequently found that they are intimately associated with a Carboniferous limestone.

The Mesozoic sedimentary rocks exposed along Kuskokwim River between the mouth of the Holitna and Georgetown and in an area situated chiefly on the headwaters of the Holitna but extending southward into the valleys of the Mulchatna and Chulitna were described by P. S. Smith[26] under four subdivisions, including, from oldest to youngest, the "conglomerate of Cairn Mountain," the "Mesozoic shales south of the Kuskokwim," the "Mesozoic sandstones south of the Kuskokwim," and the "Mesozoic sedimentary rocks north and west of the Holitna." Smith believed that the first three of these subdivisions are in part Jurassic, but this opinion was not based on paleontologic evidence. The writer suspects that all the subdivisions may be conformable members of the Upper Cretaceous. Smith's description of these rocks includes discussions of the distribution, topographic expression, lithologic character, structure, age, and correlation of each subdivision, with statements by T. W. Stanton concerning fossils from the "shales south of the Kuskokwim" which he considered as indicating an indefinite position in the Mesozoic, probably Jurassic or Cretaceous, and from the "rocks north and west of the Holitna" which he regarded as probably Upper Cretaceous.

The Upper Cretaceous rocks of the area between Kuskokwim River and Iditarod were described by Mertie and Harrington[27] under the heading "Upper Cretaceous and Eocene rocks." These rocks were "thought to be mainly of Upper Cretaceous age, though grading upward into the Eocene," but the supposed Eocene beds are not known within the Kuskokwim region. The description includes a general account of the supposed Upper Cretaceous and Eocene rocks of the entire Ruby-Kuskokwim region, with local details concerning certain areas, among which are the Takotna and Tatalina Valleys[28] and the district from "Iditarod to Kuskokwim River,[29]

[26] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 57–84, 1917.

[27] Mertie, J. B., jr., and Harrington, G. L., The Ruby-Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 754, pp. 24–41, pl. 4, 1924.

[28] Idem, pp. 31–32.

[29] Idem, pp. 35–36.

which lie within the region here under discussion. The description of the district from Iditarod to Kuskokwim River is an abstract of the description by P. S. Smith. The discussion of the "flora, fauna, and age"[30] contains lists of fossils as identified by Stanton and by Hollick. Among these fossils are several collections from the Kuskokwim region.

Stratigraphic description.—No detailed stratigraphic studies of the Cretaceous rocks of the Kuskokwim region have yet been made, but the published observations of Spurr and Smith furnish the basis for some tentative generalizations concerning the general stratigraphic sequence. The general succession of beds appears to be, as might be expected, somewhat similar to the section on the Yukon.

The base of the Upper Cretaceous rocks was found, according to Spurr,[31] about 10 miles below Vinasale, where Devonian limestone is overlain unconformably by thin-bedded gray arkose and conglomerate. These younger rocks are comparatively unaltered and, according to Spurr, closely resemble the Cretaceous rocks of the Yukon. The conglomerate is coarse, containing some pebbles 5 or 6 inches in diameter. Spurr states that "rocks of this same appearance outcrop all along the river as far as the Holiknuk." The shale and sandstone show lateral intergradations within short distances. No fossils were seen except abundant but poorly preserved plant remains. One specimen of a post-Jurassic dicotyledonous leaf was collected. The strike from the contact with the Devonian rocks to the mouth of the Holiknuk is in general but not everywhere parallel to the course of the river, and the dip is in general but not uniformly to the northwest. Both in this section and in that on the Yukon River near Melozi the basal Cretaceous rocks are conglomerate, shale, and sandstone, which overlie limestone that is presumably Devonian. In each section obscure plant remains are abundant, but well-preserved plants are rare, and marine fossils are absent. The writer believes that the Cretaceous rocks on the Kuskokwim above the mouth of the Holitna are to be correlated with the basal conglomeratic rocks (Ungalik conglomerate) of the Yukon section and possibly with part or all of the overlying fresh-water shale and sandstone (Melozi formation). The rocks south of the Kuskokwim that were described by Smith[32] as the "conglomerate of Cairn Mountain" resemble the lower conglomeratic division of the Cretaceous sections on Yukon and Kuskokwim rivers in lithologic character and in stratigraphic relations and are, in the writer's opinion, to be correlated with that division. The "conglomerate of Cairn Mountain" consists of beds

[30] Mertie, J. B., jr., and Harrington, G. L., op. cit., pp. 39–41.
[31] Spurr, J. E., op. cit., p. 125.
[32] Smith, P. S., op. cit., pp. 58–63.

of coarse and fine conglomerate with some coarse sandstone. Cobbles a foot or more in smallest diameter are by no means uncommon, but most of the pebbles are less than 3 inches in diameter. Most of the larger pebbles consist of igneous rocks, and the smaller ones of dark slate, with some limestone, chert, quartzite, and vein quartz. A pebble of calcareous sandstone containing Devonian fossils was found. Smith does not state the thickness of the conglomerate, but it may be inferred[33] to be much more than 300 feet. Although no rocks are exposed directly beneath the conglomerate, it dips away from a supposed Devonian limestone, on which it is believed to rest unconformably.

The rocks exposed on Kuskokwim River from the mouth of the Holitna to a place about 14 miles below Kolmakof were described by Spurr[34] as limestone, shale, and arkose. Some of the shale is carbonaceous and contains coal fragments. Abundant plant remains were noted, but they are presumably only fragmentary, as no fossil plants were collected. Marine fossil shells (*Inoceramus*) were obtained at two localities. The rocks exposed along the Kuskokwim between the mouth of the Holitna and the Parks quicksilver mine and in the hills between the mouth of the Holitna and Iditarod were described by Smith[35] as chiefly shale and sandstone. Some coarse sandstone and fine conglomerate with a calcareous matrix was found, but no limestone was seen. The sandstone contains abundant fragments of vegetable remains, but no well-preserved fossil plants were found. Marine fossils (chiefly *Inoceramus*) were found at several localities. The rocks exposed on the Kuskokwim near Kolmakof were described by Smith and Maddren[36] as thin-bedded sandstone and shale aggregating at least 4,000 to 5,000 feet in thickness, overlain conformably by arkosic sandstone at least 1,000 feet thick. Marine fossils (*Inoceramus*) were obtained in the arkosic sandstone.

The rocks exposed along the Kuskokwim from the mouth of the Holitna to a place about 14 miles below Kolmakof and in the hills north of the river are chiefly shale and sandstone, which have yielded marine fossils at several localities. The writer believes that these rocks correspond to the marine sandstone and shale (Nulato formation) of the Yukon section. This area may also contain some rocks corresponding to the coal-bearing Kaltag formation, which overlies the Nulato, and to the fresh-water shale and sandstone (Melozi formation), which underlie the Nulato, but no evidence of them has been recorded.

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[33] Smith, P. S., op. cit., p. 61.
[34] Spurr, J. E., op. cit., pp. 126–130.
[35] Smith, P. S., op. cit., pp. 77, 84.
[36] Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region: U. S. Geol. Survey Bull. 622, p. 282, 1915.

South of the Kuskokwim, throughout an area extending southward from the divide between Stony and Hoholitna Rivers across the valley of the Mulchatna to Chulitna River just west of Lake Clark, Smith found some Mesozoic shale and sandstone overlying the "conglomerate of Cairn Mountain" (see pp. 437–438), which he considered as at least partly Jurassic but which, in the writer's opinion, should be correlated with the Upper Cretaceous rocks exposed on the Kuskokwim.

The rocks described by Smith[37] as "Mesozoic shales south of the Kuskokwim" are composed mainly of nearly black shale, but include in almost every large exposure some beds of sandstone. These rocks are believed to lie conformably upon the "conglomerate of Cairn Mountain" and are apparently overlain unconformably by the "Mesozoic sandstones south of the Kuskokwim." No estimate of their thickness has been made. Organic remains are very uncommon in them, but small fragments of plant remains were seen in some of the finer sandstone and fragments of pelecypod shells (probably a Jurassic or Cretaceous *Inoceramus*) were found at one locality at the contact with the overlying sandstone. Smith states that these rocks "resemble so closely the Upper Cretaceous rocks described elsewhere [north of the Kuskokwim] that the two must be separated not by differences in lithology but by differences in structure." The lithologic character of these rocks, as well as their relation to the underlying conglomerate, indicates, in the writer's opinion, that they are to be correlated with the fresh-water shale and sandstone (Melozi formation) of the Upper Cretaceous section on the Yukon and probably with some of the unfossiliferous shale and sandstone exposed on the Kuskokwim.

The rocks described by Smith[38] as "Mesozoic sandstones south of the Kuskokwim" consist of a great thickness of beds which are composed dominantly of sandstone but contain also some conglomerate and shale. In many of the exposures it is difficult to tell whether the sandstone or the shale predominates. What is supposed to be the basal bed is a fine conglomerate which appears to rest unconformably on the underlying shale. The only traces of organic remains are fragmentary bits of vegetable material. The writer believes that these rocks are the equivalent of some of the sandstone and shale exposed along the Kuskokwim and are possibly to be correlated with the upper arkosic sandstone near Kolmakof and with the marine sandstone and shale (Nulato formation) of the Upper Cretaceous section on the Yukon.

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[37] Smith, P. S., The Lake Clark-central Kuskokwim region, Alaska: U. S. Geol. Survey Bull. 655, pp. 63–72, 1917.

[38] Idem, pp. 72–77.

The rocks exposed along the Kuskokwim from a point 14 miles below Kolmakof to the bend about 8 miles below Ohagamut are chiefly volcanic. They were included by Spurr[39] in the "Kolmakof series," which he regarded as Cretaceous and as the volcanic lateral equivalent of the "Holiknuk series." Maddren[40] has shown, however, that these rocks include upper Carboniferous limestone and tuff. The writer believes that the rocks described by Spurr as the "Kolmakof series" include three or four distinct units, namely, Upper Cretaceous sandstone and shale, which are the direct western extension of Spurr's "Holiknuk series," the associated igneous rocks, which are dikes and sills and not lava; late Paleozoic or early Mesozoic tuff (and lava?) associated with upper Carboniferous limestone; and possibly late Tertiary volcanic rocks like those on the lower Yukon.

Age and correlation.—The Upper Cretaceous rocks of the Kuskokwim region have yielded the fossils listed in the following table:

Upper Cretaceous fossils from Kuskokwim River[a]

	—	11	13	9087	9088	9219	9222	9223	9224	9225	9226	9227	9228
Dicotyledenous leaves	a											b	
Inoceramus (large broad form)				b									
Inoceramus		b	b		b		b	b	b	b	b		b
Inoceramus?						b							
Ostrea											b		b

[a] a, Identified by F. H. Knowlton; b, identified by T. W. Stanton.

——. Kuskokwim River about halfway between the Chagavenapuk and Vinasale. J. E. Spurr, 1898.

11. South bank of Kuskokwim River midway between Yukwonilnuk River and camp of August 5. J. E. Spurr, 1898.

13. North bank of Kuskokwim River about 3 miles above Kolmakof. J. E. Spurr, 1898.

9087. North bank of Kuskokwim River about 1½ miles above Kolmakof. A. G. Maddren, 1914.

9088. North bank of Kuskokwim River about 3 miles below Kolmakof. A. G. Maddren, 1914.

9219 (14AS82). Hill south of camp of July 17, north of Mulchatna River. P. S. Smith, 1914.

9222 (14AS134), 9223 (14AS135), 9224 (14AS136), 9225 (14AS136a). Station LXIII, George-Kuskokwim divide. P. S. Smith, 1914.

9226 (14AS166). Station LXXXVII. P. S. Smith, 1914.

9227 (14AS167). Near station LXXXVIII, near Georgetown-Iditarod trail. P. S. Smith, 1914.

9228 (14AS170). 1 mile west of station LXXXVIII, Georgetown-Iditarod trail. P. S. Smith, 1914.

[39] Spurr, J. E., A reconnaissance in southwestern Alaska in 1898: U. S. Geol. Survey Twentieth Ann. Rept., p. 7, pp. 130–131, 161–163, 182–183, 1900.

[40] Maddren, A. G., unpublished notes.

The fossils listed above, though including no identifiable species, clearly indicate the Upper Cretaceous age of the rocks from which they came. The *Inoceramus* of lot 9087, according to Stanton, is of an Upper Cretaceous type, and the two lots of dicotyledonous leaves are also indicative of the Upper Cretaceous. It has also been shown on the preceding pages that the lithologic character of the rocks and the stratigraphic sequence are very similar to those of the section of Upper Cretaceous rocks on the lower Yukon. The lower plant-bearing conglomerate above the mouth of the Holitna is probably to be correlated with the Ungalik conglomerate and possibly with part or all of the Melozi formation. The marine shale and sandstone exposed along the Kuskokwim from the Holitna to a point 14 miles below Kolmakof and in the hills north of the river are to be correlated with the Nulato formation. The "conglomerate of Cairn Mountain" south of the Kuskokwim is probably the equivalent of the Ungalik conglomerate. The "Mesozoic shales south of the Kuskokwim," which lie conformably on the "conglomerate of Cairn Mountain," are probably to be correlated with the Melozi formation. The apparently unconformably overlying "sandstones south of the Kuskokwim" are possibly the equivalent of the marine sandstone of the Nulato formation. The equivalent of the coal-bearing Kaltag formation has not been recognized in the Kuskokwim Valley.

KOYUKUK VALLEY

GENERAL FEATURES

The Cretaceous rocks of the Koyukuk Valley include the Lower Cretaceous limestone, lava, and tuff of the Koyukuk group; the Upper Cretaceous shale, sandstone, and conglomerate near the mouth of the river; and the Upper Cretaceous (?) sandstone, arkose, grit, and conglomerate of the Bergman group. The base of the Koyukuk group has not been recognized, and the rocks that may underlie it are not known. The writer suspects that the lava and tuff that have been described as part of the Koyukuk group may belong to an underlying formation. The Bergman group, which is supposed to rest upon the Koyukuk group where that group is present, directly overlies Paleozoic rocks along the northern border of its area. The Upper Cretaceous rocks in this district are not overlain by any strata other than unconsolidated Quaternary deposits, unless the coal-bearing beds at Tramway Bar, which have been tentatively included in the Bergman group, should prove to be Tertiary deposits younger than the Bergman.

LOWER CRETACEOUS

KOYUKUK GROUP

Historical review.—The Lower Cretaceous rocks of the Koyukuk Valley were first recognized in 1899 by Schrader,[41] who described them as extending down Koyukuk River for about 30 miles from a point about 15 miles above Waite Island, as consisting of impure limestone associated with amygdaloidal lava and andesitic tuff and as bearing a fauna determined by Stanton as Lower Cretaceous. A brief reference to the occurrence of these rocks has been made by Brooks.[42] Schrader[43] described these rocks in somewhat greater detail in 1902, naming them the Koyukuk "series." The final report on his investigations in northern Alaska[44] contains a redescription of the Koyukuk "series" and shows, for the first time, its areal distribution on a map.

In 1910 Smith and Eakin, crossing from the Koyukuk to the Kobuk, just west of Hogatza River, studied and mapped some rocks in the Zane Hills, which were described as the Koyukuk group.[45] The description is based primarily on the rocks in the Zane Hills, but information derived from Schrader's description of the rocks on the Koyukuk, especially concerning the age of the rocks, is included. The map shows the known areal extent of the Koyukuk group, not only in the Zane Hills but also on the Koyukuk, where as represented it occupies a somewhat less extensive area than that shown on Schrader's map. No fossils were found in the Zane Hills, but the rocks there are correlated with those on the Koyukuk on the basis of being "lithologically similar." Although Schrader's descriptions indicate that limestone is the typical and most abundant constituent of the Koyukuk group, it is stated by Smith that "limestones were entirely absent" in the Zane Hills.

A large area lying between the Yukon and the Koyukuk was mapped and studied geologically by Eakin in 1913. The Cretaceous rocks of this area, which were described by Eakin[46] as "Mesozoic sedimentary rocks," are chiefly Upper Cretaceous but may be partly Lower Cretaceous. The area which Eakin mapped[47]

[41] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk Rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Report, pt. 2, pp. 476–477, 1900.

[42] Brooks, A. H., The coal resources of Alaska: U. S. Geol. Survey Twenty-second Ann. Rept., pt. 3, p. 529, 1902.

[43] Schrader, F. C., Geological section of the Rocky Mountains in northern Alaska: Geol. Soc. America Bull., vol. 13, p. 246, 1902.

[44] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 53, 77, 97, pl. 3, 1904.

[45] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp 55, 80–82, 1913.

[46] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 41–50, 1916.

[47] Idem, pl. 2.

as "Upper Cretaceous (possibly including some Lower Cretaceous) conglomerates, grits, sandstones, slates, and shales" includes areas along Koyukuk River which were placed in the Koyukuk group by Schrader and by Smith. The description by Eakin contains no mention of any beds that resemble the Lower Cretaceous rocks described by Schrader and Smith and may be regarded as applying only to the Upper Cretaceous rocks of this region. Eakin stated that the rocks which he described "may be in part of Lower Cretaceous age," and mentioned the Lower Cretaceous fossils (p. 444) found by Schrader.

Stratigraphic description.—The Koyukuk "series" was described by Schrader[48] as follows:

The rocks of the Koyukuk series consist of pink and reddish limestone, dark shale, slates, and some sandstone or arkose, with occasional associated igneous rocks. The latter include dioritic dikes, amygdaloids, and andesitic tuffs, which denote volcanic activity during and subsequent to Lower Cretaceous time.

Owing to wide breaks in the sequence of outcrops and the changing attitude of the rocks, no attempt will be made at present to form an estimate of the thickness of the series. It may be noted, however, that at one point where fossils were collected, near the southern edge of the map, on the right (or west) bank of Koyukuk River, the limestone exhibits a thickness of about 800 feet.

The rocks that were referred to the Koyukuk group by Smith[49] were described as follows:

In the Zane Hills, where similar rocks were examined by the Survey party in 1910, limestones were entirely absent and the group consisted of agglomeratic and arkosic beds associated with basic intrusives and effusives cut by acidic intrusives. Some conglomeratic beds were recognized.

It may be seen from the foregoing statements that the Lower Cretaceous rocks on Koyukuk River have not been adequately described. The stratigraphic sequence and thickness of the Koyukuk group, the character of its basal and upper contacts, and the identity of the rocks which underlie and overlie it are all unknown. The Koyukuk group, in the writer's opinion, is a heterogeneous aggregate composed of rocks of very diverse character, origin, and age. It includes Lower Cretaceous limestone containing *Aucella crassicollis* and having a thickness estimated by Schrader at about 800 feet, and it may include some other rocks, notably some or all of the shale, slate, arkose, and conglomerate mentioned by Schrader and Smith. The "associated igneous rocks" have not been described as interbedded with the *Aucella*-bearing beds, although they certainly are intimately associated with those beds. The writer suspects that

[48] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, p. 77, 1904.

[49] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, p. 81, 1913.

they may possibly consist of pre-Cretaceous and post-Cretaceous volcanic rocks like the volcanic rocks "associated with" the Upper Cretaceous deposits on the lower Yukon. (See pp. 404, 410.) Some of the sedimentary rocks that have been included in the Koyukuk group may possibly be Upper Cretaceous.

Age and correlation.—The only fossils that have been found in the Lower Cretaceous rocks on Koyukuk River are several small lots collected by Schrader in 1899 and tabulated below. The presence of *Aucella crassicollis* shows the Lower Cretaceous age of at least the limestone members of the Koyukuk group and indicates a general correlation with the limestone and other rocks containing *Aucella crassicollis* in other Alaskan districts.

Lower Cretaceous fossils from Koyukuk River [a]

	230	261	262	315
Serpula? sp.	×			
Ostrea sp. (a small simple form)	×			
Ostrea?			×	
Avicula? sp. (fragments)	×			
Aucella crassicollis Keyserling	×	×		
Aucella?			×	×
Astarte sp.	×			
Cyprina?	×			

[a] Identified by T. W. Stanton.

230. North bank of Koyukuk River about 5 miles above Waite Island. F. C. Schrader, 1899.

261. North bank of Koyukuk River about 3 miles above lower end of Waite Island. Limestone at least 800 feet thick. F. C. Schrader, 1899.

262. North bank of Koyukuk River about 3 miles below lower end of Waite Island. Limestone and tuff. F. C. Schrader, 1899.

315. Koyukuk River near north end of Roundabout Mountain. Boulder on river bank. F. C. Schrader, 1899.

UPPER CRETACEOUS

SHALE AND SANDSTONE ON THE LOWER KOYUKUK

Historical review.—On the lower reaches of Koyukuk River, between Kateel River and the mouth of the Koyukuk, Schrader observed some sedimentary and associated igneous rocks which have proved to be in part Upper Cretaceous. These rocks are not described specifically in Schrader's text, but are referred to in the statement that the Nulato sandstone "probably also covers a considerable area in the lower part of the Koyukuk Basin, near the mouth of the river."[50] The map[51] accompanying Schrader's report indi-

[50] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk Rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, p. 478, 1900.

[51] Idem, pl. 60.

cates "sandstone, arkose, grit, conglomerate, limestone, shale, mud rock with plant remains, volcanic tuff, breccia, and altered igneous rocks" as exposed along the lower part of the river. The sedimentary rocks of this area were mapped by Smith and Eakin [52] as the Shaktolik group, and the volcanic rocks as Tertiary or Recent basalt, but no description was given of the exposures on the Koyukuk.

Stratigraphic description.—The Upper Cretaceous rocks on the lower Koyukuk were described by Schrader as including sandstone, shale, conglomerate, and limestone. No information concerning the details of the stratigraphy is available, but it is believed that these rocks probably include the equivalent of several and perhaps all of the members of the Upper Cretaceous section exposed on the Yukon between Melozi and Louden. The exposures next below Kateel River include grit and conglomerate that are probably the equivalent of the lower conglomeratic member near Melozi. The igneous rocks exposed along the lower 30 miles of the Koyukuk are the northern extension of some of the post-Cretaceous volcanic rocks of the Yukon. The intervening exposures are possibly the equivalent or one or more of the subdivisions of the Upper Cretaceous on the Yukon. No estimate of the thickness of the Upper Cretaceous rocks on the lower Koyukuk has been made. Their base has not been recognized, but it is believed that basal conglomerate rests upon pre-Upper Cretaceous rocks near the mouth of Kateel River. Their upper contact is probably beneath the Quaternary silt in the high bluff about 20 miles (35 or 40 miles by the river) north of Koyukuk village. This bluff separates exposures of Upper Cretaceous plant-bearing sandstone and shale from exposures of the supposed Tertiary volcanic rocks, which are probably the next younger consolidated rocks.

Age and correlation.—Fossils have been obtained at only one locality in the Upper Cretaceous rocks on the lower Koyukuk. These fossils include both plants and a marine invertebrate, as listed below, and are too few to give any conclusive evidence on the precise position of these beds relative to the section of the Yukon. One of the plants is known only at this locality; the other occurs in the lower fresh-water shale and sandstone (Melozi formation) of the Yukon section. The marine invertebrate indicates that the beds may correspond to either the marine sandstone and shale of the Nulato formation or to one of the marine beds in the Kaltag formation of the Yukon section.

[52] Smith, P. S., and Eakin, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: U. S. Geol. Survey Bull. 449, pl. 5, 1911.

7472 (333). West bank of Koyukuk River about 40 miles above mouth. Sandstone and shale. F. C. Schrader, 1899. *Hedera* n. sp., *Platanus* n. var. Identified by C. A. Hollick.

2183 (334). West bank of Koyukuk River about 40 miles above mouth. From sandstone and shale at the same locality as 7472. F. C. Schrader, 1899. *Mya?*. Identified by T. W. Stanton.

UPPER CRETACEOUS (?)

BERGMAN GROUP

Historical review.—The supposed Upper Cretaceous rocks of the upper course of Koyukuk River were first described by Schrader[53] as the Kenai "series." The description states that the rocks are "composed of impure sandstone, arkose, grit, and conglomerate, indiscriminately carrying more or less lignite and remains of fossil plants. On account of its fossil contents and its resemblance to the Kenai found elsewhere in the Yukon district, this formation is provisionally referred to the Kenai." These rocks were subsequently named the Bergman "series" by Schrader.[54] The later description contains a brief general account of the lithologic character, a statement that on the north these rocks rest unconformably on supposed Silurian schist and on the south they are apparently infolded with the Koyukuk "series," and a discussion of age in which it is said that "no fossils beyond undeterminable lignitic plant remains have thus far been found in the Bergman series. From its apparent close relations, however, to the Koyukuk series it seems that the Bergman series is probably Cretaceous."

Mendenhall, while on his way from Fort Hamlin to Kotzebue Sound in 1901, crossed the Koyukuk Valley by way of Kanuti and Alatna rivers. He gives a description[55] of the lithologic character of the Bergman "series" at the localities where he observed it and shows its areal distribution on geologic maps. The description contains no account of the stratigraphic sequence and no conclusive evidence as to the age.

The Bergman "series" was redescribed by Schrader[56] in 1904. The description includes a general account of the lithologic character, structure, and relation to the adjacent rocks and a statement that these rocks are referred tentatively to the Cretaceous because of "the seemingly close relationship of the Bergman series to the

[53] Schrader, F. C., Preliminary report on a reconnaissance along the Chandalar and Koyukuk Rivers, Alaska, in 1899: U. S. Geol. Survey Twenty-first Ann. Rept., pt. 2, p. 477, 1900.

[54] Schrader, F. C., Geological section of the Rocky Mountains in northern Alaska: Geol. Soc. America Bull., vol. 13, pp. 246–247, 1902.

[55] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: U. S. Geol. Survey Prof. Paper 10, pp. 39–41, pls. 5, 7, 1902.

[56] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 53, 77–79, 97, pl. 3, 1904.

Lower Cretaceous or Koyukuk series, and the bituminous character of its coal content."

The structural and stratigraphic position of the Bergman "series" was briefly discussed by Brooks,[57] who stated that the Bergman "series" may underlie the Koyukuk "series" and "be chiefly lower Mesozoic, with some infolded Kenai beds."

The upper part of the Koyukuk Valley was visited in 1909 by Maddren, but his description of the Cretaceous rocks[58] was based chiefly on the earlier observations by Schrader and Mendenhall, as his observations were mostly outside the area occupied by these rocks. The description apparently applies to the Cretaceous rocks of the entire Koyukuk Valley and includes both the Bergman and Koyukuk "series," although the Koyukuk does not occur within the area covered by Maddren's map.

The exposures of these rocks in the Koyukuk and Kobuk Valleys were described by Smith[59] as the Bergman group which he referred to the Upper Cretaceous. Smith's description was based largely on his observations of the western extension of these rocks along Kobuk River (see pp. 449–451) but includes information derived from his own observations of the exposures on the lower courses of Alatna River and from Schrader's and Mendenhall's observations on the Koyukuk and its tributaries, including John, Alatna, and Kanuti Rivers. The resemblance of these rocks to the Upper Cretaceous Ungalik conglomerate and Shaktolik group of the Nulato-Norton Sound district is noted. This resemblance and the fact that the Bergman group is supposed to overlie and is less deformed than the Koyukuk group form the basis of its assignment to the Upper Cretaceous.

In a report on a district lying between the Koyukuk and the Yukon Eakin[60] described "Mesozoic sedimentary rocks," which are represented on his map as extending into the type area of the Bergman group. The main part of the description deals with the southwestern extension of this area, where these rocks are mapped as forming a continuous belt extending from the type locality of the Bergman group to the well-known exposures of Upper Cretaceous rocks on Yukon River below Melozi, which have already been described. (See pp. 401–404.)

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[57] Brooks, A. H., The geography and geology of Alaska: U. S. Geol. Survey Prof. Paper 45, pp. 235–236, 237, 1906.

[58] Maddren, A. G., The Koyukuk-Chandalar region, Alaska: U. S. Geol. Survey Bull. 532, pp. 32, 34, 53–55, 56, pl. 5, 1913.

[59] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp. 55, 84–87, pl. 2, 1913.

[60] Eakin, H. M., The Yukon-Koyukuk region, Alaska: U. S. Geol. Survey Bull. 631, pp. 24, 41–50, pl. 2, 1916.

Stratigraphic description.—The Bergman "series" was described by Schrader[61] as follows:

The term Bergman is here employed to designate a group of comparatively uniform rocks covering a large area in the Koyukuk Basin and forming in large part the Koyukuk Plateau. This series lies north of the Koyukuk series and has a north-south extent of 60 to 70 miles. On the north it rests unconformably on the schists of the Totsen series, while on the south it is apparently infolded with the Koyukuk series, to which it is supposed to be closely related and which it is supposed to succeed in geologic age.

The Bergman series consists essentially of thin or medium bedded impure gray or brownish sandstone and dark slate, with some dark shale and occasionally conglomerate, but along the north it is bordered by a belt of conglomerate about 10 miles wide, which is apparently the basal member. The sediments of the series have been derived very largely from igneous rocks, as is shown by the generally feldspathic constituents of the sandstones and the presence of basaltic, diabasic, and granitic pebbles or finer detritus in the conglomerate on the lower part of Alatna River and at Lookout Mountain. The supposed basal belt of conglomerate along the northern border, however, so far as it was observed in the John River region, is composed essentially of the débris of limestone and mica schist derived from the Skajit formation and the Totsen series, on which latter it unconformably lies. This conglomerate is normally coarse and in some instances contains boulders.

Owing to the wide separation of the outcrops visited, data for forming an adequate estimate of the thickness of the Bergman series have not been obtained. From a general impression, however, it seems safe to suggest that it is probably at least 2,000 feet.

Age and correlation.—The Bergman group has yielded no fossils, but its assignment to the Cretaceous and probably to the Upper Cretaceous is believed to be well grounded. The beds of the Bergman group seen by the writer near Bettles are not unlike the Upper Cretaceous shale and sandstone of the Innoko and Iditarod districts. They also resemble some of the Lower Cretaceous slate and quartzite of the Upper Yukon and may possibly include both Upper and Lower Cretaceous beds. It is also possible that some of the beds that have been included in the Bergman group, notably the coal-bearing beds at Tramway Bar, may be Tertiary.

KOBUK VALLEY

GENERAL FEATURES

The only rocks in the Kobuk Valley that have been assigned to the Cretaceous are the supposed western extension of the Bergman group, which has been mapped as trending westward from the upper Koyukuk across the headwaters of the Kobuk and along the divide between the Kobuk and Selawik. The rocks that have been referred to the Bergman group in the Kobuk Valley consist of con-

[61] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 77–78, 1904.

glomerate, sandstone, and shale, which lie uncomformably upon Paleozoic rocks and are succeeded, though they are not known to be directly overlain, by supposed Tertiary coal-bearing rocks.

UPPER CRETACEOUS (?)

BERGMAN GROUP

Historical review.—The supposed Upper Cretaceous rocks of the Kobuk Valley were observed by Mendenhall in an exploratory journey down the Kobuk in 1901. These rocks were described by Mendenhall[62] as the Bergman "series," the description consisting of brief statements concerning the lithology and structure of the rocks seen at various places on the upper Kobuk with a general discussion concerning the possible age of the "series."

The exposures of these rocks in the upper part of the Kobuk Valley and in the hills south of the Kobuk were studied in 1910 by Smith and Eakin,[63] who included them in rocks that they briefly described as "Mesozoic and Tertiary (?) rocks." The same field observations were recorded in greater detail by Smith,[64] who described these rocks as the Bergman group and discussed their distribution, lithologic character, structure, and age. Part of the rocks described by Smith as the Bergman group had been included by Mendenhall[65] in a "metamorphic complex," which he described as probably chiefly Paleozoic.

Stratigraphic description.—The exposures of the Bergman group in the Kobuk Valley were described by Mendenhall,[66] as follows:

On the Kowak, a few miles above the outlet of Lake Nutavukti, conglomerates are exposed which, although exhibiting some variations from the type, are regarded as belonging to the Bergman series. The conglomeratic beds are here interbedded with red and green shales, and a considerable body of soft red sandstones occurs in one locality. In the conglomerate occur pebbles of slate, greenstone, and other types, which are recognized as derived from the older rocks to the north.

Through the mile gorge, a short distance above the outlet of Norutak Lake, the Kowak flows along the strike of a slaty phase of the Bergman, which is very similar lithologically to a belt crossed along the Allen nearly due east of here. The slates in the canyon of the Kowak carry small limestone lenses and are cut by narrow quartz stringers. They have been only very slightly metamorphosed.

Below the gorge the river enters a broad filled valley with no rock exposures until the mouth of the Reed River is reached. Here slaty shales, similar to

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[62] Mendenhall, W. C., Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska: U. S. Geol. Survey Prof. Paper 10, pp. 39–42, pls. 5, 7, 1902.

[63] Smith, P. S., and Eakin, H. M., The Shungnak region, Kobuk Valley: U. S. Geol. Survey Bull. 480, pp. 284–286, 1911.

[64] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp. 84–87, pl. 2, 1913.

[65] Mendenhall, W. C., op. cit., pp. 31–37.

[66] Idem, pp. 39–40.

those in the gorge above, are found in outcrop and exhibit a northerly dip, while those in the gorge dip toward the south. Five or six miles farther downstream soft green fractured sandstones and graywackes, frequently weathering red, are encountered.

A short distance above the mouth of Pah River the hills south of the Kowak are found to be composed of these same Bergman beds. The shales predominate here, and the topographic forms to which they give rise extend westward to the head of the Kuikcherk River and eastward as far as can be seen.

The following description was given by Smith:[67]

Dominantly, the Bergman group is a series of dark greenish-gray arkosic conglomerates and sandstones. The base of the section exposed on Alatna River, on the lower part of John River, and on the upper part of the Kobuk is a conglomerate made up of pebbles of the older rocks, namely schists, limestones, vein quartz, and igneous rocks, such as greenstones and granites. The beds are thoroughly indurated and are usually more resistant than the higher sandstones. As a result, they form conspicuous pinnacled ridges, particularly in the range north of the Kobuk from Beaver River westward to the Mauneluk. It is because of similarity in topographic expression in this particular that the hills south of the Kobuk from Ambler River westward are correlated with the areas of Upper Cretaceous rocks. This division corresponds closely in all physical features with the Ungalik conglomerate, of probable Upper Cretaceous age, described in the extreme eastern part of Seward Peninsula and the adjacent Norton Bay region.

Toward the top of the lower division sandstones become more numerous, and at its top the group is composed almost entirely of sandstones which are practically indistinguishable from the sandstones of the Shaktolik group of the more southern part of the Koyukuk basin. The rock is medium fine grained, of rather uniform texture, and generally of a greenish-gray color. It is thoroughly indurated and offers fair resistance to weathering, not so great resistance, however, as most of the rocks already described. As a result, the sandstone portion of the Bergman group generally forms somewhat rounded, coarsely dissected hills of medium elevation.

The rock contains abundant fragments of rather angular ferromagnesian minerals and feldspars, whose glittering faces and partial crystal outline resemble the phenocrysts of an igneous rock. Generally, the beds are rather massive, showing no pronounced stratification. At many places, however, beds of dark shale interlaminated with the sandstones serve to bring out the structure. No extensive exposures of the shales were observed by the expeditions of 1910 or 1911, but Mendenhall notes belts of shale many hundred feet thick. He also notes red and green shales in the Kobuk basin near Lake Nutavukti, but such shales have not been recognized in other parts of the region.

Fragments of what appears to be wood and lignitic beds have been found here and there in the sandstone member. A bed of lignite occurs in the hills immediately east of Pah River, and another near Tramway Bar on the North Fork of the Koyukuk, but both beds are apparently thin and of poor quality. Owing to the absence of determinative fossils some areas in the central part of the Kobuk basin mapped provisionally as Tertiary may prove to be Upper Cretaceous, in which case workable lignite beds may on closer examination be found in the Bergman group.

[67] Smith, P. S., op. cit. (Bull. 536), pp. 84–85.

Age and correlation.—Neither the rocks in the Kobuk Valley referred to the Bergman group nor the rocks of the type area of the group in the Koyukuk Valley have yielded any fossils, and their assignment to the Upper Cretaceous is not beyond doubt. The evidence on the age of the Bergman group in the Koyukuk Valley is discussed on page 449.

COLVILLE VALLEY

GENERAL FEATURES

The Cretaceous rocks of the Colville Valley include marine Lower Cretaceous and Upper Cretaceous rocks exposed on Anaktuvuk River, a tributary of the Colville. As most of the Arctic slope is unexplored, the extent of the Cretaceous rocks is not known. They are not present in the Canning River district, 100 miles east of the Colville, or along the Canadian boundary. They probably extend westward for a considerable distance and may extend as far as Cape Lisburne, nearly 400 miles west of the Colville, where Jurassic rocks are overlain by rocks that are probably Lower Cretaceous.

The Lower Cretaceous rocks of the Colville Valley, which have been described as the Anaktuvuk "series," consist of sandstone at least 2,000 feet thick with subordinate amounts of conglomerate and shale, contain *Aucella crassicollis*, and are believed to rest unconformably upon Carboniferous and possibly Devonian rocks, although the actual contact is concealed beneath a broad belt of Quaternary deposits. The Upper Cretaceous rocks of the Colville Valley, which have been described as the Nanushuk "series," consist chiefly of sandstone, limestone, and shale of undetermined thickness, with some coal beds, contain marine fossils, apparently overlie the Lower Cretaceour unconformably, and are probably overlain unconformably by Tertiary beds.

LOWER CRETACEOUS

ANAKTUVUK GROUP

The Lower Cretaceous rocks of the Anaktuvuk group were first described by Schrader[68] as the Anaktoovuk "series." The description consists of a brief general discussion of the character, occurrence, structure, and age of the rocks. Reference is made to the determination by Stanton of Lower Cretaceous fossils (*Aucella crassicollis*), but Stanton's report on the fossils is not quoted in full. These rocks were subsequently described by Schrader in somewhat greater detail,[69] but on the basis of the same field work, as the Anak-

[68] Schrader, F. C., Geological section of the Rocky Mountains in northern Alaska: Geol. Soc. America Bull., vol. 13, pp. 245–246, 1902.

[69] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 53, 74–76, pl. 3, 1904.

tuvuk "series." The localities (544 and 545, on "Anaktuvuk River, cross ridge below camp of August 1") where Schrader collected fossil plants from the rocks of the Anaktuvuk group were cited by Ward,[70] but no list or description of the fossils was given. The fossils from these localities consist of indeterminate stems. A description of the Anaktuvuk group based wholly on Schrader's description has been given by Smith.[71]

Stratigraphic description.—The Anaktuvuk group was described by Schrader as consisting chiefly of impure sandstone or arkose with a little fine conglomerate. The sandstone is mostly heavy bedded, many beds being 6 or 8 feet thick, and is generally fine or medium grained, but some beds are so coarse as to be almost a grit. The color ranges from dark or bluish gray to dirty green. The coarser rock commonly has a speckled appearance and seems to be composed of grains of variously colored flint. Some of the beds contain detritus from igneous rocks, such as fragments of feldspar and ferromagnesian minerals. The igneous rocks from which this detritus came have not been recognized. Conglomerate seems to be rare, having been seen at only one locality 2 miles below the mouth of Willow Creek. It is rather fine, few of the pebbles being more than three-quarters of an inch in diameter. The pebbles are notably angular and consist mainly of white quartz and dark slate-colored flint. The cementation is firm but not as strong as in the neighboring Paleozoic rocks. The exact stratigraphic position of this conglomerate has not been determined, but it seems to be above the middle of the group. No accurate measurement of the thickness of the Anaktuvuk group has been made, but Schrader estimates it to be at least 2,000 feet.

The Anaktuvuk group was believed by Schrader to rest unconformably on Carboniferous or Devonian rocks, but the basal contact is concealed beneath a belt of Quaternary deposits 8 miles wide. It is possible that this concealed interval contains Triassic or Jurassic rocks, such as Leffingwell has described (see pp. 103–105, 262–268) as overlying the Carboniferous rocks 100 miles east of Anaktuvuk River. The Anaktuvuk is succeeded on the north by the Upper Cretaceous rocks of the Nanushuk formation. Schrader believed that these Upper Cretaceous rocks immediately overlie the Anaktuvuk group and that the structural discordance between the two suggests unconformity.

Age and correlation.—The evidence on the age of the Anaktuvuk group is found in several lots of fossils collected by Schrader at dif-

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[70] Ward, L. F., Status of the Mesozoic floras of the United States (second paper): U. S. Geol. Survey Mon. 48, p. 146, 1905.

[71] Smith, P. S., The Noatak-Kobuk region, Alaska: U. S. Geol. Survey Bull. 536, pp. 82–84, pl. 2, 1913.

ferent localities on Anaktuvuk River. The fossils of lot 538–540, which were obtained from the lowest of the known fossiliferous beds, near the base of the exposures of the Anaktuvuk group on Anaktuvuk River, include *Aucella crassicollis*, which is regarded as characteristic of the Lower Cretaceous rocks of Alaska. The other lots of marine fossils—including 546–548, obtained near the middle of the group, 551–556, somewhat higher; and 560, near the top of the group—are less characteristic and are said by Stanton to be "probably of Cretaceous age, though they do not include any strictly characteristic genera." These fossils offer no evidence that the upper part of the Anaktuvuk group may not be Upper Cretaceous.

Lower Cretaceous fossils from Anaktuvuk group [a]

	538–540	544	545	546–548	551–556	560
Stems [b]		×	×			
Worm burrow				×		
Trails					×	
Cucullaea sp. (internal cast)					×	
Cucullaea ? sp. (imprint)					×	
Inoceramus sp.						×
Inoceramus ? sp. (young)					×	
Aucella crassicollis Keyserling	×					
Thracia ? sp. (imprint)					×	
Astarte sp.					×	
Dentalium sp.				×		
Gastropod (small slender form)				×	×	

[a] Identified by T. W. Stanton, except as noted.
[b] Identified by W. M. Fontaine.

538–540. Mountain east of camp of July 29 on Anaktuvuk River.[71a] Impure calcareous sandstone. F. C. Schrader, 1901.

544. Ridge east of camp of August 1 on Anaktuvuk River. Dark dirty-gray sandstone or arkose. F. C. Schrader, 1901.

545. River bank in canyon below camp of August 1 on Anaktuvuk River. Dark dirty-gray sandstone or arkose. F. C. Schrader, 1901.

546–548. River bank in canyon below camp of August 1 on Anaktuvuk River. Fine-grained gray sandstone at same locality as 545. F. C. Schrader, 1901.

551–556. Anaktuvuk River at mouth of Willow Creek. Fine-grained gray sandstone. F. C. Schrader, 1901.

560. Anaktuvuk River 2 miles below camp of August 4. Rusty-gray arkose. F. C. Schrader, 1901.

UPPER CRETACEOUS

NANUSHUK FORMATION

Historical review.—The Upper Cretaceous rocks of the Nanushuk formation were first described by Schrader [72] as the Nanushuk "series." The original description includes a brief account of the occurrence and character of the rocks, with a list of fossils identified

[71a] The position of these camps is given in Prof. Paper 20, pl. 3.
[72] Schrader, F. C., Geological section of the Rocky Mountains in northern Alaska: Geol. Soc. America Bull., vol. 13, pp. 247–248, 1902.

by T. W. Stanton. A later account by Schrader,[73] though based on the same field work, describes the rocks in greater detail.

Stratigraphic description.—The Nanushuk formation was described by Schrader[74] as follows:

> The rocks of the Nanushuk series are best exposed in the north bank of the Anaktuvuk about 5 miles above the mouth of Tuluga River. The exposure occurs in a bluff about three-eighths of a mile long that rises steeply 120 feet above the river. The rocks, which here have a steep dip, are mainly thin bedded. The beds range from 3 to 6 inches in thickness and exhibit rapid alternation. They consist of gray and brown sandstone, generally fine grained and sometimes friable, with some gray and impure fossiliferous limestone, dark shale, fine-grained gray quartzite, drab-colored and green chert, and black slate, stained reddish along the joints. Coal of good quality is also present.

The Nanushuk formation is believed to overlie the Anaktuvuk group unconformably, Schrader stating that "the unconformity between the Anaktuvuk and the Nanushuk is inferred from the difference in the topography and the marked change in the character and attitude of their rocks. In the most northern observed exposure of the Anaktuvuk the dip is north, while in the most southern of the Nanushuk it is steeply south."

The Nanushuk formation is succeeded by the Tertiary beds of the Colville "series." Schrader[75] states that the Colville "series" "apparently overlies" the Nanushuk formation but does not describe the precise relations on the contact.

Age and correlation.—The Nanushuk formation has yielded the marine fossils listed below. Concerning lot 3206 Stanton said: "This lot is certainly of Upper Cretaceous age. The species are all apparently different from those with which I am familiar, but several of them are of types known only in the Upper Cretaceous."

Upper Cretaceous fossils from Nanushuk formation [a]

	3206	3207		3206	3207
Nucula, n. sp.	a		Tellina, n. sp.	a	
Glycimeris, n. sp.	a		Tellina, n. sp.	a	
Inoceramus	a		Tellina	a	
Avicula	b		Siliqua	b	
Modiolus, n. sp.	a		Pelecypods	a	
Thracia, n. sp.	a		Haminea	a	
Thracia?	a		Gastropod	a	
Astarte, n. sp.	a		Scaphites	b	
Pelecypods (Veneridae)		b			

[a] a, Identified by W. R. Smith; b, identified by T. W. Stanton.

3206 (565–606). Anaktuvuk River 5 miles above mouth of Tuluga River. Gray sandstone. F. C. Schrader, 1901.

3207 (609–612). Anaktuvuk River about 7 miles below mouth of Nanushuk River. Gray calcareous sandstone. F. C. Schrader, 1901.

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[73] Schrader, F. C., A reconnaissance in northern Alaska: U. S. Geol. Survey Prof. Paper 20, pp. 53, 79–81, pl. 3, 1904.
[74] Idem, p. 79.
[75] Idem, p. 81.

NORTHWESTERN ALASKA

GENERAL FEATURES

The supposed Cretaceous or Jurassic rocks of northwestern Alaska include the plant and coal bearing beds that have been described as the Corwin formation, which are apparently entirely of non-marine origin, and an overlying unnamed formation composed of sandstone and shale. These rocks apparently have a wide distribution, for they are exposed continuously along the coast from a point about 25 miles east of Cape Lisburne, near Corwin Bluff, to a point about 50 miles farther east, near Cape Beaufort, and occur also near Wainwright Inlet, which is 180 miles northeast of Cape Lisburne, and at several inland localities, at some of which coal has been reported. The Corwin formation has been studied in detail along the coast between Cape Lisburne and Cape Beaufort, where the general sequence of Mesozoic and associated rocks may be represented as in the following section, which is a modification of a section given by Collier.[76] The principal changes from Collier's section are indicated by asterisks (*).

Section of Cretaceous or Jurassic and associated rocks near Cape Lisburne and Corwin Bluff

	Feet
Quaternary*: Sand, gravel, silt, talus, ground ice, etc	100+
Unconformity.	
Lower Cretaceous (?)*: Sandstone interbedded with shale, nonfossiliferous	10,000+
Conformity.	
Cretaceous or Jurassic*: Corwin formation, composed of calcareous and carbonaceous shale with sandstone and conglomerate at infrequent intervals. Many coal beds and plants. No marine fauna	15,000+
Unconformity or hiatus due to faulting.*	
Upper Triassic*: Thin-bedded shale, slate, chert, and limestone. Marine invertebrate fauna	1,000+
Unconformity or hiatus due to faulting.*	
Lower Carboniferous (Mississippian):	
Lisburne formation, composed of massive limestone interbedded with white chert. Extensive coral and bryozoan fauna	3,000+
Hiatus due to faulting, conformity (?).*	
Thin-bedded black shale, slate, and limestone, and several coal beds. Lower Carboniferous flora and fauna (?)	500+
Conformity (?).	
Devonian (?): Calcareous sandstone and slate. No fossils found	2,000+

[76] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, p. 16, 1906.

CRETACEOUS OR JURASSIC

CORWIN FORMATION

Historical review.—The first accounts of the rocks now referred to the Corwin formation were given by Beechey [77] and by Collie,[78] who was surgeon on Captain Beechey's voyage on the *Blossom* in 1825 to 1828. Collie described briefly the lithologic character of the coal-bearing rocks 35 miles from Cape Lisburne and near Cape Beaufort and noted the presence of "carbonized impressions of reeds, both fluted and plain, generally flat." These accounts were the basis of the description by Grewingk,[79] who erroneously assigned the rocks at Cape Beaufort to the Carboniferous because of the presence of coal at that locality and of Carboniferous fossils not far away at Cape Lisburne and Cape Thompson.

The next account of these rocks was given by Woolfe,[80] who collected some fossil plants at an undescribed locality on the coast northeast of Cape Lisburne. These plants formed the basis of the first description of the fossils of the Corwin formation by Lesquereux,[81] who subsequently described [82] a larger collection that was also obtained by Woolfe, presumably at the same locality. These fossils were assigned by Lesquereux to the Neocomian. They have been discussed by Ward,[83] who regarded them as "Lower Cretaceous or possibly Upper Jurassic," and by Knowlton,[84] who accepted Lesquereux's age determination without comment. The coal-bearing rocks at Cape Beaufort were described by Dall and Harris [85] and also by Dall [86] under the heading "Cape Beaufort coal measures." With Dall's paper is an appendix by Knowlton [87] which

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[77] Beechey, F. W., Narrative of a voyage to the Pacific and Beering's Strait. Pt. 1, p. 270, London, 1831.

[78] Collie, Alex., in Buckland, William: The zoology of Captain Beechey's voyage, pp. 173–174, London, 1839.

[79] Grewingk, C., Beitrag zur Kenntniss der orographischen und geognostischen Beschaffenheit der nord-west Küste Amerikas mit den anliegenden Inseln: Russ. ka. min. Gesell. St. Petersburg verh., 1848–49, pp. 163–164, 323, 333, 344.

[80] Woolfe, H. D., The seventh or Arctic district: Report on population and resources of Alaska at the Eleventh Census, pp. 132–133, 1893.

[81] Lesquereux, Leo, List of recently identified fossil plants belonging to the United States National Museum, with descriptions of several new species: U. S. Nat. Mus. Proc., vol. 10, p. 36, 1887.

[82] Lesquereux, Leo, Recent determinations of fossil plants from Kentucky, Louisiana, Oregon, California, Alaska, Greenland, etc., with descriptions of new species: U. S. Nat. Mus. Proc., vol. 11, pp. 31–33, 1888.

[83] Ward, L. F., The geographical distribution of fossil plants: U. S. Geol. Survey Eighth Ann. Rept., pt. 2, p. 926, 1888.

[84] Knowlton, F. H., A review of the fossil flora of Alaska, with descriptions of new species: U. S. Nat. Mus. Proc., vol. 17, pp. 211, 213, 215, 216–217, 232–236, 1894.

[85] Dall, W. H., and Harris, C. D., Correlation papers—Neocene: U. S. Geol. Survey Bull. 84, p. 249, 1892.

[86] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 819–820, 1896.

[87] Knowlton, F. H., Report on the fossil plants collected in Alaska in 1895 as well as those previously known from the same region: Idem, pp. 876–897.

contains a list of the fossil plants from the Cape Lisburne region similar to that published by Knowlton in 1894.

The Corwin formation was named in 1902 by Schrader,[88] who described it as the Corwin "series," the type locality being at Corwin Bluff, about 30 miles east of Cape Lisburne. The reason why Schrader used this new formation name instead of the older name, "Cape Beaufort," of Dall and Harris or Beaufort, was evidently a suspicion that Grewingk's reference of the rocks at Cape Beaufort to the Carboniferous might be at least partly correct. Schrader said: "It is possible that the rocks at Cape Beaufort may on further research prove to be older than the Jura-Cretaceous, but for the present it seems best to include them in the Corwin series." Schrader gave a more detailed account[89] of the Corwin in 1904, describing the formation as extending as far along the coast as Wainwright Inlet, 180 miles northeast of Cape Lisburne, where he obtained fossil plants similar to those at Corwin Bluff. The fossil plants collected by Woolfe in 1884, together with some additional material obtained by H. D. Dumars in 1890 and by Schrader in 1901, have been described in detail by Fontaine,[90] who considered that their age is "not older than the Lower Oolite and not younger than the Lower Cretaceous but probably is between them."

These rocks were studied in considerable detail in 1904 by Collier,[91] who described them as the Corwin formation. Collier's report includes a brief discussion of the fossil plants by Knowlton,[92] who referred them to the Jurassic. Knowlton subsequently[93] gave a detailed description of the fossil plants collected by Collier, with a full discussion of their age.

The rocks exposed along the northwest coast of Alaska, especially in the valleys of Kukpowruk, Utukok, and Meade Rivers and near Wainwright Inlet, were studied by Paige, Foran, and Gilluly in 1923 in connection with the investigation of Naval Petroleum Reserve No. 4. A preliminary report on these investigations[94] contains a general description of the supposed Cretaceous or Jurassic plant-

[88] Schrader, F. C., Geological section of the Rocky Mountains in northern Alaska: Geol. Soc. America Bull., vol. 13, pp. 244–245, 1902.

[89] Schrader, F. C., A reconnaissance in northern Alaska in 1901: U. S. Geol. Survey Prof. Paper 20, 1904, pp. 72–74.

[90] Fontaine, W. M., Plants from the vicinity of Cape Lisburne, Alaska (in Ward, L. F., Status of the Mesozoic floras of the United States, second paper): U. S. Geol. Survey Mon. 48, pp. 153–175, pls. 39–45, 1905.

[91] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, pp. 16, 27–30, 36–42, 1906.

[92] Knowlton, F. H., Report on Mesozoic fossil plants from northwestern Alaska: U. S. Geol. Survey Bull. 278, pp. 29–30, 1906.

[93] Knowlton, F. H., The Jurassic flora of Cape Lisburne, Alaska: U. S. Geol. Survey Prof. Paper 85, pp. 39–64, pls. 5–8, 1914.

[94] Paige, Sidney, Foran, W. T., and Gilluly, James, A reconnaissance of the Point Barrow region, Alaska: U. S. Geol. Survey Bull. 772, pp. 11–20, 1925.

bearing and coal-bearing rocks that are believed to be the northeast extension of the Corwin formation, with detailed descriptions of the exposures on Kukpowruk, Utokok, and Meade Rivers and on the streams tributary to Wainwright Inlet. Discussions and lists by Knowlton, Hollick, and Reeside of the fossils obtained by Paige and his associates are given. These new collections of fossils yield evidence, which will be discussed on pages 465–466, that the flora of the Corwin formation may belong in the Lower Cretaceous, where it was placed in the earlier investigations, rather than in the Jurassic, where it was placed by Knowlton.

Stratigraphic description.—The Corwin formation, according to Collier,[95]—

consists of rather thinly bedded shales, sandstones, conglomerates, and coal beds. Fossil plants occur in the shales wherever they have been closely examined. The shales which comprise the greater part of the formation vary in composition from greenish-brown calcareous to black carbonaceous beds and in texture from mudstones to fine-grained sandy shales. The sandstones, which occur at infrequent intervals throughout the formation in beds usually less than 10 feet thick, are easily traceable over eroded areas, since their outcrops rise in relief above the surrounding shales. The conglomerates are made up mainly of quartz and chert pebbles from one-half inch to 4 inches in diameter. The most definite bed of this kind, which is about 15 feet in thickness and reaches the coast at Corwin Bluff, forms a prominent ridge from 100 to 200 feet high.

The coal beds are a very striking and characteristic feature of the formation, 40 coal beds being indicated by Collier[96] in his columnar section. The coal is in general distributed throughout the formation, but the thicker beds occur in two groups about 8,000 feet apart.

The Corwin formation apparently contains no beds of marine deposition. Coal beds and plant-bearing shale are distributed throughout the formation. Marine fossils and deposits of probable marine origin, such as limestone, have not been found, except the limestone reported by Schrader as occurring near Wainwright Inlet and Cape Beaufort. In view of the apparent terrestrial origin of the formation and of its great thickness, the prevalence of fine-grained material is noteworthy.

The thickness of the Corwin formation is stated by Collier to be at least 15,000 feet, as estimated from the exposures along the coast. These exposures are fairly continuous, and it seems improbable that there can be any duplication of the beds by faulting, unless it is by faults that are nearly parallel to the bedding. Collier[95] states that "there is no evidence of faulting other than minor shearing movements parallel with the bedding planes." The writer suggests that a

[95] Collier, A. J., op. cit., p. 28.
[96] Idem, pl. 9.

multitude of such small faults might cause a considerable aggregate amount of thickening which would be very difficult to detect, and that in view of the apparent enormous thickness of the formation and more especially in view of the apparent range of a single flora throughout so great a thickness of strata, it may perhaps be safe to assert the probability of a considerable aggregate amount of duplication in thickness by small movements on numerous bedding faults.

The base of the Corwin formation has never been observed, nor is it known what formation underlies it. The next oldest rocks occurring in this district are the Triassic beds at Cape Lisburne (pp. 106–112). These have not been observed in contact with the Corwin formation, except possibly at Cape Thompson, where the Triassic beds are overlain conformably by black shale which Kindle [97] has suggested may be the equivalent of the Corwin formation. No definite evidence in support of this correlation or on the age of this shale has yet been obtained.

The Corwin formation is overlain, probably conformably, by the Cretaceous (?) sandstone and shale described on page 467.

The rocks exposed on Kukpowruk, Utukok, and Meade Rivers and near Wainwright Inlet that are supposed to represent the northeast extension of the Corwin formation were described by Paige, Foran, and Gilluly [98] as follows:

A thick series of sandstone, shale, thin-bedded limestone, and associated beds of coal extends from Cape Beaufort westward to the Cape Lisburne region. These rocks are believed to extend eastward to and beyond Cape Simpson and inland at least 80 miles south of the coast at Meade River.

The sandstone is gray where fresh but weathers to a yellow or buff color. It is medium to fine grained, grades in places into shale and rarely into conglomerate, and in general is of normal types that were laid down at the margin of or in the sea by rivers and streams that entered it. Cross-bedding and ripple marks are locally abundant.

The shale is gray to yellow, many beds are fine grained mud rocks, and some beds are darkened by an appreciable amount of carbonaceous débris. In places it grades into sandy shale or sandstone, of which shale is the normal accompaniment in deposition of the type suggested above.

The limestone is gray to brownish and occurs in beds intercalated with the shale, into which it grades. It was noted only in very thin layers or as nodular concretions.

The coal that accompanies these rocks is abundant and occurs in beds of workable thickness. In the regions of strong folding it is of bituminous rank, and in the less disturbed regions it is of subbituminous rank.

The bottom of the series was not seen, nor is it possible to estimate from the data in hand how many feet of strata have been removed by erosion. By direct measurement and by estimates from observed dips it is known that the coal-

[97] Kindle, E. M., The section at Cape Thompson, Alaska: Am. Jour. Sci., 4th ser., vol. 24, p. 528, 1909.

[98] Paige, Sidney, Foran, W. T., and Gilluly, James, A reconnaissance of the Point Barrow region, Alaska: U. S. Geol. Survey Bull. 722, pp. 12, 17, 1925.

bearing portion of this sedimentary series is not less than 7,000 feet thick and may be considerably more and that a non coal-bearing portion beneath the coal is at least 2,000 feet thick and in all probability much more. An estimate of the entire thickness of these rocks can not be made at this time, though it may be stated with considerable assurance as more than 15,000 feet. The series is therefore comparable in thickness to the Corwin formation.

Age and correlation.—The evidence on the age of the Corwin formation is to be found almost wholly in its fossil plants. The field relations of the rocks indicate merely that they are post-Triassic, and the fossils other than plants are few and not characteristic. The fossils of the Corwin formation and of the beds that are believed to be equivalent to it are listed in the following table. In the table an attempt has been made to indicate the stratigraphic occurrence of the species as far as possible. The first 17 lots, all collected by Collier and his assistants from the type section of the Corwin formation, are arranged in geographic order from east to west. This order, unless undetected faults are present, is also the stratigraphic sequence, beginning at the base. The other lots could not be placed in similar order but are arranged in several groups, including miscellaneous collections from the type area of the Corwin formation, which could not be placed in stratigraphic sequence, followed by collections from Kukpowruk River, Utukok River, Wainwright Inlet, and Meade River in geographic sequence.

Fossils from the Corwin formation [a]

	4AW25	4AC11	4AC10	4AC9	4AW18	4AC8	4AC7	4AC82	4AW26	4AW12	4AW8	4AW17	4AW9	4AW1	4AW4	4AW5	4AW11	H. D. W.	H. D. D.	644	666	672	4AC12	O. H.	7640	7641	7644	7645	7646	7647	7648	7649	7650	7651	7652	7653	7654	12178	7665	7666	7668	657	658	660	661	7699	7700	7701
Chondrites filiciformis Lesquereux																		a																														
Coniopteris burejensis (Zalessky) Seward				b													b																															
Coniopteris hymenophylloides (Brongniart) Seward			b	b																																												
Dicksonia saportana Heer																		a																														
Cladophlebis alata Fontaine?		b		b		b				b	b				b		b	a	a														b			b				b								
Cladophlebis huttoni (Dunker) Fontaine	b	b		b						b							b	a	a				b																					a				
Cladophlebis vaccensis Ward																		a																														
Cladophlebis																																									b							
Oleandridium																																									b							
Onychiopsis psilotoides (Stokes and Webb) Ward																		a	a																													
Onychiopsis																																									b							
Fern (new)																																									b							
Taeniopteris																																															b	
Taeniopteris?																											b																					
Equisetum collieri Knowlton			b													b																																
Otozamites giganteus Thomas																b																																
Otozamites beani (Lindley and Hutton) Seward																								b																								
Podozamites lanceolatus (Lindley and Hutton) Fr. Braun																b																																
Podozamites lanceolatus eichwaldi (Schimper) Heer	b													b		b		b																											b		b	
Zamites megaphyllus (Phillips) Seward								b										b	b																										b			
Baiera gracilis (Bean) Bunbury																																											a					
Baiera																																																b
Ginkgo digitata (Brongniart) Heer	b	b	b	b	b	b			b					b					a																													
Ginkgo huttoni (Sternberg) Heer																		a																														
Ginkgo huttoni magnifolia Fontaine?																			a																													
Ginkgo sp.=(Ginkgodium? alaskense Fontaine)																		b	b																													
Ginkgo																																	b			b												
Taxites olriki Heer?																																							b									
Taxites zamiodes? (Leckenby) Seward																																															b	
Taxites																																			b													
Elatides curvifolia (Dunker) Nathorst																b																																
Pinus?																																														b		
Pityophyllum nordenskiöldi (Heer) Seward																b																																
Fieldenia nordenskiöldi Nathorst						b									b																																	
Pagiophyllum kurrii (Pomel) Schimper																b																																
Pagiophyllum steenstrupi Bartolin?						b																																										
Pagiophyllum																																																b
Phoenicopsis angustifolia Heer																b																																
Phoenicopsis speciosa Heer	b	b		b		b	b				b	b	b	b		b																								b							b	
Phoenicopsis?																										b		b		b				b														
Coniferous leaves																																						b										

[a] a, Identified by W. M. Fontaine; b, identified by F. H. Knowlton; c, identified by T. W. Stanton; d, identified by J. B. Reeside, jr.

Fossils from the Corwin formation—Continued

	4AW25	4AC11	4AC10	4AC9	4AW18	4AC8	4AC7	4AC82	4AW26	4AW12	4AW8	4AW17	4AW9	4AW1	4AW4	4AW5	4AW11	H. D. W.	H. D. W.
Coniferous wood																			
Stems																			
Macerated fragments of plants																			
Dicotyledenous leaves																			
Worm burrows																			
Ostrea sp., large simple form																			
Pecten sp																			
Pelecypod related to Anisocardium but probably a new genus																			
Thracia sp																			
Tellina sp																			
Trails of crustaceans?																			

	644	666	672	4AC12	O. H.	7640	7641	7644	7645	7646	7647	7648	7649	7650	7651	7652	7653	7654	12178	7665	7666	7668	657	658	660	661	7699	7700	7701
Coniferous wood													b																
Stems	a		a					b		b										b			a				b		
Macerated fragments of plants						b						b																	
Dicotyledenous leaves														b															
Worm burrows		c																											
Ostrea sp., large simple form																			d										
Pecten sp																			d										
Pelecypod related to Anisocardium but probably a new genus																			d										
Thracia sp																			d										
Tellina sp																			d										
Trails of crustaceans?																		b											

4AW25. Shale about 4 miles east of the mouth of Thetis Creek, in sea cliff, about 1 mile east of Cape Sabine and about 400 or 500 feet below Thetis seam No. 5. C. W. Washburne, 1904.

4AC11. 4 miles east of Corwin Bluff. A. J. Collier, 1904.

4AC10. 3 miles east of Corwin Bluff. A. J. Collier, 1904.

4AC9. 2⅘ miles east of Corwin Bluff. A. J. Collier, 1904.

4AW18. Thetis Creek about 1½ miles from mouth. C. W. Washburne, 1904.

4AC8. 2¼ miles east of Corwin Bluff. A. J. Collier, 1904.

4AC7. 2 miles east of Corwin Bluff. A. J. Collier, 1904.

4AC82. Beach at mouth of creek east of Corwin Bluff. A. J. Collier, 1904.

4AW26. Mouth of creek east of Corwin Bluff. Boulder. C. W. Washburne, 1904.

4AW12. Mouth of creek east of Corwin Bluff. C. W. Washburne, 1904.

4AW8. Boulder at mouth of creek 100 yards east of Corwin Bluff. C. W. Washburne, 1904.

4AW17. Shale at base of conglomerate at Corwin Bluff. C. W. Washburne, 1904.

4AW9. Foot of Corwin Bluff. C. W. Washburne, 1904.

4AW1. Shale above the big conglomerate at Corwin Bluff. Mostly from 16-foot coal bed 1 mile west of Corwin Bluff. C. W. Washburne, 1904.

4AW4. Concretions in shale just west of mouth of small creek about 1½ miles west of Corwin Bluff. C. W. Washburne, 1904.

4AW5. Scattered through shale for 200 feet west of 4AW4. C. W. Washburne, 1904.

4AW11. Carbonaceous shale 3¾ miles west of Corwin Bluff. Below a big sandstone. C. W. Washburne, 1904.

H. D. W. "Near Cape Lisburne" (probably near Corwin Bluff). Henry D. Woolfe, 1884.

H. D. D. Corwin coal mine. H. D. Dumars, 1890.

664, 666. Cape Beaufort. F. C. Schrader, 1901.

672. "Lisburne coal mines," near Corwin Bluff. F. C. Schrader, 1901.

4AC12. Cape Beaufort. A. J. Collier, 1904.

O. H. Labeled "4 miles south of Cape Lisburne" but probably from Corwin mine. Oscar Hershey, 1906.

7640 (1). Low ridge 10 miles east of Cape Beaufort. Stratigraphic position probably near the top of the Kukpowruk coal series. W. T. Foran, 1923.

7641 (11). Kukpowruk River 5 miles from mouth, near bottom of coal series. W. T. Foran, 1923.

7644 (14). Shale below 10-foot bed of coal 5 miles up Kukpowruk, near bottom of coal series. W. T. Foran, 1923.

7645 (15). Shale below 1-foot bed of coal 5 miles up Kukpowruk. W. T. Foran, 1923.

7646 (16). Sandstone associated with coal 5 miles up Kukpowruk River, near bottom of coal series. W. T. Foran, 1923.

7647 (17). Kukpowruk River 4¾ miles from mouth, near bottom of coal series. W. T. Foran, 1923.

7648 (18). Parting in 10-foot bed of coal, Kukpowruk River 5 miles from mouth, near bottom of coal series. W. T. Foran, 1923.

7649 (19, 20, 21, 22). Kukpowruk River 6 miles from mouth, approximately 2,000 feet stratigraphically above 10-foot coal bed mentioned above. W. T. Foran, 1923.

7650 (23). Kukpowruk River 10 miles above mouth, approximately the same position as 22. Axis of shallow syncline; rocks nearly horizontal. W. T. Foran, 1923.

7651 (24). Kukpowruk River 17 miles from mouth, at junction of forked stream. Position in series not known; probably near top. W. T. Foran, 1923.

7653 (28). Kukpowruk River 18 miles from mouth, probably near top of coal series. W. T. Foran, 1923.

7652 (27). Kukpowruk River 22 miles above mouth, probably near top of coal series. W. T. Foran, 1923.

7654 (35). Kukpowruk River 40 miles from mouth, approximately 1,000 feet stratigraphically below coal series, in zone of disturbance. W. T. Foran, 1923.

12178 (100, 101). Thin conglomerate bed 43 miles above mouth of Kukpowruk River. About 1,000 feet stratigraphically below coal series. W. T. Foran, 1923.

7665 (C). Utukok River 15 miles from mouth. The strata on Utukok River are nearly horizontal, therefore all specimens collected on this river (7664, 7665, 7666, 7668) must be approximately in the same stratigraphic position. W. T. Foran, 1923.

7666 (E). Utukok River 17 miles from mouth. W. T. Foran, 1923.

657. About 7 miles southwest of Wainwright Inlet. Slightly calcareous shale. F. C. Schrader, 1901.

658. About 7 miles southwest of Wainwright Inlet. Slightly calcareous sandstone. F. C. Schrader, 1901.

660. About 7 miles southwest of Wainwright Inlet. Dense slightly calcareous sandstone. F. C. Schrader, 1901.

661. About 7 miles southwest of Wainwright Inlet. Indurated shale. F. C. Schrader, 1901.

7699 (1). About 27 miles up Meade River, on right bank. Poor exposure, possibly float of coal-bearing shale and sandstone. Sidney Paige, 1923.

7700 (2). Right bank of Meade River 33 miles above mouth. Poor exposure of sandstone and shale. Sidney Paige, 1923.

7701 (3). Meade River 67 miles above mouth. Horizontal shale, sandstone, and coal. Sidney Paige, 1923.

The flora of the rocks that were subsequently described as the Corwin formation was considered by Lesquereux[1] "probably Neocomian." Additional collections, which were also obtained from the type locality of the Corwin formation, were studied by Fontaine,[2] who said:

> The age of the formation yielding the Alaskan fossils, as indicated by them, is not older than the Lower Oolite and not younger than the Lower Cretaceous but is probably between them.

The larger collections that were obtained by Collier from the type section of the Corwin formation were studied in detail by Knowlton,[3] who concluded that

> The Corwin formation of the Cape Lisburne region is undoubtedly Jurassic in age, belonging either in the upper part of the Middle Jurassic or Brown

[1] Lesquereux, Leo, Recent determinations of fossil plants from Kentucky, Louisiana, Oregon, California, Alaska, Greenland, etc., with descriptions of new species: U. S. Nat. Mus. Proc., vol. 11, p. 31, 1888.

[2] Fontaine, W. M., Plants from the vicinity of Cape Lisburne, Alaska (in Ward, L. F., Status of the Mesozoic floras of the United States; second paper): U. S. Geol. Survey Mon. 48, p. 175, 1905.

[3] Knowlton, F. H., The Jurassic flora of Cape Lisburne, Alaska: U. S. Geol. Survey Prof. Paper 85–D, p. 43, 1914.

Jura, or the extreme lower portion of the Upper Jurassic or White Jura—that is to say, it is probably not older than the Bathonian and certainly not younger than the Oxfordian.

Knowlton regarded the flora of the entire formation as a unit, saying,[4] "so far as the data at hand indicate, there is little or no variation in the flora throughout the whole thickness of the formation."

The fossil plants collected by Paige and Foran in 1923 at several localities on the supposed northeastern extension of the Corwin formation include fossils that are similar to some of those in the type section of the Corwin formation, together with dicotyledenous leaves and other fossils that are indicative of the Lower Cretaceous. Knowlton[5] made the following statements concerning some of these collections:

7650. Kukpowruk River 10 miles above mouth. This is by all odds the most puzzling lot in the whole collection. The *Ginkgo*, although large and well enough preserved, is of little value in fixing the age, as *Ginkgo* has come down to us from the Jurassic to the present with very little change. The fragment of a fern seems to be the same as a form from Cape Lisburne, but the well-defined dicotyledons absolutely preclude a reference to the Jurassic. On the basis of present knowledge it can hardly be older than the middle or upper part of the Lower Cretaceous.

7653. Kukpowruk River 18 miles from mouth, probably near top of coal series. These forms are similar to forms found in the Cape Lisburne Jurassic, but considering the report on No. 7650, I hesitate to call it Jurassic. No dicotyledons are present.

7668. Utokok River 43 miles above mouth. The age appears to be Lower Cretaceous, in the approximate position of the Kootenai or Wealden.

7665. Utokok River [15 miles from mouth]. Age can not be fixed by this specimen. May be Tertiary.

Arthur Hollick also examined the fossil plants collected by W. T. Foran along Kukpowruk and Utokok Rivers and made the following statements[6] concerning them:

Most of these collections consist of a single piece of matrix each. Plant remains are included in most of them, but they are fragmentary, and few are identifiable, even generically. Certain of the single specimens, however, if considered by themselves, would be regarded as almost certainly Jurassic; but at least one and possibly two of the collections undoubtedly represent Lower Cretaceous horizons, viz:

7650. Kukpowruk River, 10 miles above mouth. This collection, in addition to more or less well defined specimens of a fern (*Cladophlebis* sp.) and a gymnosperm (*Ginkgo* sp.), contains fragmentary remains of leaves of angiosperms. This precludes the possibility of Jurassic age for the rock in which they occur. The age is Lower Cretaceous and apparently about the equivalent of the Potomac group.

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[4] Knowlton, F. H., op. cit., p. 40.

[5] Knowlton, F. H., quoted by Paige, Sidney, Foran, W. T., and Gilluly, James, op. cit., pp. 13–14.

[6] Hollick, Arthur, idem, pp. 14–15.

7668. Utokok River, 43 miles above mouth. This collection, consisting of a single piece of matrix, contains plant remains, mostly fragments of ferns, among which are specimens of *Oleandridium* sp. and *Cladophlebis* sp. The age appears to be Lower Cretaceous and equivalent to the Kootenai formation.

The only identifiable fossils, other than plants, that have been obtained from the Corwin formation or from its supposed extension along the northwest coast of Alaska are some marine shells collected by W. T. Foran in 1923 from a thin conglomerate bed 43 miles from the mouth of the Kukpowruk and about 1,000 feet stratigraphically below the coal series. Concerning these fossils (lot 12178) Reeside[7] said:

I have not been able to identify this fauna with any degree of certainty. The species present are probably all new and might come equally well from the Upper Jurassic, Lower Cretaceous, or Upper Cretaceous. It impresses me as more likely to be Upper Cretaceous than older.

The flora of the Corwin formation does not show a close relationship with any of the undoubted Jurassic floras of southern Alaska. One of the species occurring in the Corwin formation, *Fieldenia nordenskiöldi* Nathorst, has been doubtfully identified from the Middle Jurassic Tuxedni sandstone of Cook Inlet. *Phoenicopsis speciosa* Heer occurs in the Upper Jurassic Chinitna shale of Cook Inlet. *Coniopteris burejensis* (Zallesky) Seward occurs in the Upper Jurassic Shelikof formation of the Alaska Peninsula. *Zamites megaphyllus* (Phillips) Seward occurs in the Upper Jurassic Naknek formation of the Alaska Peninsula. The flora of the Corwin formation shows a closer relationship with the flora of the Kennicott formation, which is regarded as Lower Cretaceous. Four species, *Otozamites beani* (Lindley and Hutton) Seward, *Zamites megaphyllus* (Phillips) Seward, *Taxites zamiodes*? (Leckenby) Seward, and *Elatides curvifolia* (Dunker) Nathorst, have been identified as occurring in the Corwin and Kennicott formations.

The probability that the Corwin formation is Cretaceous instead of Jurassic is suggested by the above-cited apparent lack of relationship with any of the undoubted Jurassic floras of Alaska, by its closer relationship with the Kennicott formation, which is classified as Lower Cretaceous (see pp. 335–349), by the presence of several species which Lesquereux, Fontaine, and Ward considered Lower Cretaceous, and especially by the presence of dicotyledonous leaves.

LOWER CRETACEOUS (?)

SANDSTONE AND SHALE NEAR CAPE LISBURNE

The youngest of the supposed Cretaceous rocks near Cape Lisburne comprise sandstone and shale, which overlie the Cretaceous or Juras-

[7] Reeside, J. B., jr., quoted by Paige, Sidney, Foran, W. T., and Gilluly, James, op. cit., p. 15.

sic rocks of the Corwin formation with apparent conformity. They have yielded no fossils but are believed to be possibly Lower Cretaceous and perhaps the general equivalent of the Anaktuvuk group. They are the youngest rocks known in the Cape Lisburne district.

These rocks were described by Collier[8] under the heading "Upper Mesozoic beds" and were mapped as "Cretaceous (?) sandstones and shales." Collier described briefly the lithology and the stratigraphic and structural relations of these beds to the adjacent so-called Carboniferous and Jurassic rocks and discussed their thickness and age and correlation. The southern extension of these rocks is possibly found in some shale that overlies the Upper Triassic rocks at Cape Thompson and has been briefly mentioned by Kindle.[9]

The Corwin formation of the Cape Lisburne district, which has been described above (see pp. 456–466) and which is of Cretaceous or Jurassic age, is apparently overlain conformably by nonfossiliferous sandstone and shale, which are estimated to be at least 5,000 feet and perhaps 10,000 or 15,000 feet thick. These beds have been described by Collier[10] as an unnamed formation of upper Mesozoic and probably of Cretaceous age. They consist of sandstone and shale, the former predominating. They differ from the beds of the underlying Corwin formation in that the sandstone is less gritty and contains no conglomeratic material, they include no coal, and fossils are absent or at least so rare that they have not yet been found. The only evidence of the age of these beds is their apparently conformable superposition on the Cretaceous or Jurassic beds of the Corwin formation. No younger rocks are known in this district, these beds being overlain by Triassic rocks that are thrust over them.

SUMMARY

STRATIGRAPHY

LOWER CRETACEOUS

The Lower Cretaceous rocks of Alaska consist of shale, sandstone, limestone, and conglomerate, which have been recognized at many localities throughout much of the Pacific coastal region and of the Yukon and Kuskokwim Valleys and at more isolated localities in northern Alaska.

In the Pacific coastal belt these rocks rest, for the most part, on Upper Jurassic sedimentary rocks. In the interior region, where

[8] Collier, A. J., Geology and coal resources of the Cape Lisburne region, Alaska: U. S. Geol. Survey Bull. 278, pp. 30–31, pl. 1, 1906.

[9] Kindle, E. M., The section at Cape Thompson, Alaska: Am. Jour. Sci., vol. 28, p. 528, 1909.

[10] Collier, A. J., op. cit., pp. 30–31.

Jurassic rocks are absent, they rest either on Triassic beds or on different Paleozoic sedimentary formations or on schist of undetermined age. In northern Alaska the basal relations of the Cretaceous rocks are not known.

The Lower Cretaceous rocks contain a scanty marine fauna which has not been thoroughly studied but which contain two or more species of *Aucella* related to *Aucella crassicollis* Keyserling and *Aucella piochii* Gabb, together with a few other fossils, most of which are not known to be characteristic of definite horizons.

The Lower Cretaceous rocks of the Alaska Peninsula include two supposedly conformable formations, the Staniukovich shale, containing *Aucella piochii*, below, and the Herendeen limestone, containing *Aucella crassicollis*, above. The Staniukovich shale is underlain with apparent conformity by Upper Jurassic rocks. The Herendeen limestone is overlain with probable unconformity by Upper Cretaceous rocks.

In the Matanuska Valley the Lower Cretaceous rocks include conglomeratic tuff and arkose with *Aucella crassicollis* at the base, overlain conformably by the Nelchina limestone. The basal Lower Cretaceous beds rest with apparent conformity on Upper Jurassic rocks. The Nelchina limestone has been observed only on hilltops but is believed to be succeeded unconformably by Upper Cretaceous rocks.

The Lower Cretaceous rocks of the Chitina Valley as herein described include the Kennicott formation, which is composed of yellowish sandstone and greenish sandy shale that carry several species of *Aucella*, abundant ammonites, and other marine fossils and a fossil flora that Knowlton has referred to the Upper Jurassic. The Kennicott formation lies unconformably on Upper Triassic rocks and is believed to be succeeded conformably by Upper Cretaceous shale. The Kotsina conglomerate and some limestone and sandstone that probably overlie it are believed to be possibly Lower Cretaceous and possibly to represent lateral westward gradations from the Kennicott formation. Some conglomerate and grit on Nikolai and Dan Creeks may also be the equivalents of the basal Kennicott beds.

The Lower Cretaceous rocks of the Nutzotin Mountains consist of shale and graywacke that contain *Aucella crassicollis.* They have not been accurately separated from some Upper Jurassic shale and graywacke that are supposed to underlie them conformably. The next younger rocks at present known are Tertiary sedimentary and volcanic beds.

The rocks that have been assigned to the Lower Cretaceous in southeastern Alaska consist for the most part of shale or slate, sandstone or graywacke, and conglomerate. They are distinguishable, in the writer's opinion, from the somewhat similar slaty rocks that

have been referred to the Upper Jurassic by containing the Cretaceous rather than the Jurassic type of *Aucella*, by containing no volcanic beds, by containing conglomerate with granitic pebbles that are believed to have been derived from the supposed Jurassic intrusive rocks, and by showing in some places a lesser degree of metamorphism than the Jurassic slate. The Lower Cretaceous beds are believed to lie unconformably on Upper Jurassic and older rocks. They are overlain unconformably in some places by Tertiary beds, no Upper Cretaceous rocks having been found in southeastern Alaska.

Along the upper Yukon between Eagle and Woodchopper there are Lower Cretaceous slate and quartzite, several thousand feet thick, carrying *Aucella crassicollis*, that are believed to lie unconformably on Upper Triassic and Paleozoic rocks and to be succeeded unconformably by Upper Cretaceous beds.

In the Rampart-Tanana district Lower Cretaceous quartzite and slate of undetermined thickness overlie Silurian and Devonian rocks and are overlain, probably unconformably, by Upper Cretaceous shale.

Lower Cretaceous rocks are known in the Kuskokwim region only from sandstone and conglomerate float carrying *Aucella crassicollis* on the west front of the Oklune (Ahklun) Mountains, east of Kuskokwim Bay. From this occurrence the rocks in the vicinity have been described as the "Oklune series," which is believed to rest unconformably on late Carboniferous or early Mesozoic volcanic rocks and to be overlain unconformably by Upper Cretaceous conglomerate, sandstone, and shale.

The Lower Cretaceous rocks of the Koyukuk Valley have been included in the Koyukuk group, which, as originally described, includes limestone, lava, and tuff. The limestone contains *Aucella crassicollis* and is doubtless Lower Cretaceous, but the writer suspects that the supposedly associated lava and tuff may include pre-Cretaceous or post-Cretaceous volcanic rocks like those "associated with" the Upper Cretaceous rocks on the lower Yukon. The rocks beneath the Koyukuk group are not known. The Koyukuk group is supposed to be overlain unconformably by the Upper Cretaceous (?) rocks of the Bergman group.

In the Colville Valley the Lower Cretaceous rocks have been described as the Anaktuvuk group, which consists of sandstone with some conglomerate and shale. The Anaktuvuk group is at least 2,000 feet thick, contains *Aucella crassicollis*, and is believed to rest unconformably on Carboniferous and Devonian rocks and to be overlain unconformably by Upper Cretaceous rocks.

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The Lower Cretaceous may be represented on the northwest coast of Alaska by the coal-bearing rocks of the Corwin formation and by the overlying sandstone and shale. The Corwin formation, which has been considered to be more than 15,000 feet thick, is composed of shale, sandstone, and conglomerate, with many coal beds. It contains a flora which has previously been referred to the Jurassic but which the writer believes may be Lower Cretaceous. The Corwin formation probably lies unconformably on Upper Triassic rocks and is overlain with apparent conformity by shale and sandstone that may also be Lower Cretaceous. No Upper Cretaceous or Tertiary beds are known in this region.

UPPER CRETACEOUS

The Upper Cretaceous rocks of Alaska consist of shale, sandstone, and conglomerate, of which some are marine and some are nonmarine. The nonmarine rocks contain coal beds and fossil plants. The Upper Cretaceous rocks cover smaller areas than the Lower Cretaceous rocks but nevertheless are widely distributed throughout many parts of the Territory, including much of the Pacific coastal belt, exclusive of southeastern Alaska, much of the Yukon and Kuskokwim Valleys, especially in their lower and middle parts, and some localities in northern Alaska.

The Upper Cretaceous plant-bearing beds of Alaska include the middle and upper members of the Chignik formation of the Alaska Peninsula; the four formations of Upper Cretaceous shale, sandstone, and conglomerate of the lower Yukon region, some of which extend into the lower part of the Koyukuk Valley; and the shale, sandstone, and conglomerate near Seventymile River on the upper Yukon. Fossil plants are known to occur also in the Upper Cretaceous shale and sandstone near Wolverine Mountain, south of Rampart, but no determinable specimens have been available for study. Marine Upper Cretaceous rocks, in which no determinable fossil plants have yet been found, are known in the Matanuska, Chitina, Innoko, Kuskokwim, and Anaktuvuk Valleys.

The Upper Cretaceous rocks of the Alaska Peninsula have been described as the Chignik formation, which includes a lower member about 200 feet thick that consists of shale with marine fossils and no known fossil plants; a middle member about 300 feet thick that consists of shale with many coal beds and some sandstone and that contains fossil plants with a few marine mollusks; and an upper member 300 to 500 feet thick that consists of conglomerate, sandstone, and shale with fossil plants and marine invertebrates. The Chignik formation rests in some places upon Lower Cretaceous limestone with possible unconformity, and where the Lower Cretaceous

limestone is absent it rests unconformably upon Upper Jurassic rocks. It is overlain, unconformably in at least some places, by Tertiary strata. The plant-bearing beds of the Chignik formation on the Alaska Peninsula are underlain by and interbedded with marine fossiliferous strata. Most of the marine fossils were obtained from the lower member of the Chignik formation—that is, from rocks beneath the plant-bearing beds. This fauna, according to Stanton, is related to that of the Chico of California. This opinion is in reasonable accord with the evidence of the plants from the overlying beds, which Hollick believes to be possibly equivalent to the Montana.

The Upper Cretaceous rocks (Matanuska formation) of the Matanuska Valley consist of marine shale and sandstone having an aggregate thickness of at least 4,000 feet, of which the lower half is practically all shale containing abundant marine fossils, and the upper half consists of sparsely fossiliferous alternating beds of sandstone and shale, the sandstone predominating. The base of the Upper Cretaceous shale has not been observed, but the areal distribution of the formation indicates that it probably rests unconformably upon a surface of profound erosion cut across rocks that range in age from Lower Jurassic to Lower Cretaceous. The Upper Cretaceous Matanuska formation is overlain unconformably by Tertiary arkose and conglomerate.

The Upper Cretaceous rocks of the Chitina Valley consist of marine shale with some interbedded sandstone, having a total thickness of probably 7,000 or 8,000 feet. They are underlain with apparent conformity by conglomerate and sandstone that may be either basal Upper Cretaceous or Lower Cretaceous. They are believed to be succeeded by conglomeratic rocks that have been tentatively assigned to the Upper Cretaceous or basal Tertiary, above which is lava that is probably Tertiary.

The Upper Cretaceous rocks of the upper Yukon region consist of shale, sandstone, and conglomerate at least several hundred feet thick, which are believed to be underlain unconformably by Carboniferous limestone and which may be overlain by Tertiary coal-bearing rocks. The only fossils that have been obtained from these Upper Cretaceous rocks are fossil plants which indicate a correlation with the upper coal-bearing division (Kaltag formation) of the section on the lower Yukon.

The Upper Cretaceous rocks of Wolverine Mountain, in the Rampart-Tanana district, probably rest unconformably on the Lower Cretaceous slate and quartzite, consist of black, rather massive carbonaceous sandy shale, probably 200 or 300 feet thick, and contain marine mollusks and poorly preserved fossil plants. Ter-

tiary rocks, although present elsewhere in the district, are absent at this locality, and the only beds known to overlie the Upper Cretaceous rocks are Recent unconsolidated deposits.

The Upper Cretaceous rocks of the lower Yukon region consist of sandstone, conglomerate, and shale, that have an aggregate thickness of perhaps 8,000 feet. They may be separated into four formations, from the base upward (1) the Ungalik conglomerate, consisting of conglomerate, sandstone, and sandy shale about 3,000 feet thick and containing no known fossils except a few worm tubes, trails, and unidentifiable shells and vegetable remains; (2) the Melozi formation, consisting of fresh-water shale and sandstone at least 1,000 feet thick and containing fossil plants and fresh-water mollusks; (3) the Nulato formation, consisting of marine sandstone and shale perhaps 3,000 feet thick and containing marine invertebrates and a few fossil plants; and (4) the Kaltag formation, consisting of coal-bearing rocks at least 800 feet thick, which comprise fresh-water sandstone, shale, and coal beds with possibly some thin marine members, and containing fossil plants, fresh-water mollusks, and perhaps a few marine fossils. The Upper Cretaceous rocks of the lower Yukon are underlain by Paleozoic rocks and are believed to be overlain in some places by Tertiary volcanic rocks.

The Upper Cretaceous rocks of the Innoko and Iditarod valleys. which are probably the southern extension of the Upper Cretaceous rocks of the lower Yukon region, consist chiefly of marine shale and sandstone. Some beds of terrestrial (coal-bearing) sandstone that are closely associated with these rocks may be intercalated Upper Cretaceous deposits or may be infolded Tertiary sediments. These Upper Cretaceous strata are believed to rest everywhere upon Paleozoic rocks, no Lower Cretaceous or earlier Mesozoic rocks being known in this region. Their thickness is not known but is believed to be several thousand feet.

The Upper Cretaceous rocks of the Kuskokwin region consist of conglomerate, sandstone, and shale having a thickness of many thousand feet. They are believed to rest uncomformably on the Lower Cretaceous sandstone and conglomerate of the lower Kuskokwim region. Farther up the river, where the Lower Cretaceous rocks are absent, the Upper Cretaceous rocks lie unconformably on Devonian limestone. The Upper Cretaceous rocks include both marine and nonmarine members, which are believed to be the equivalent and perhaps the continuous southward extension of some or all of the Upper Cretaceous formations exposed on the lower Yukon.

The Upper Cretaceous rocks exposed on the lower Koyukuk are the northern extension of the Upper Cretaceous rocks of the lower

Yukon and may include all the formations exposed on the Yukon. They have yielded only a few fossil plants and marine mollusks that do not furnish sufficient evidence as to which of the formations exposed on the Yukon may be represented. The Bergman group of the upper Koyukuk and of an adjacent area on the headwaters of the Kobuk may also be Upper Cretaceous. The Bergman group consists of sandstone, arkose, grit, conglomerate, and shale. It is believed to be at least 2,000 feet thick. It overlies Paleozoic rocks along its northern border and is infolded with the Lower Cretaceous rocks of the Koyukuk group on the south. The Bergman group has yielded no fossils, but there is believed to be little doubt that it is, at least in part, Upper Cretaceous.

The Upper Cretaceous rocks exposed on Anaktuvuk River, a tributary of the Colville, which have been described as the Nanushuk "series," consist chiefly of sandstone, limestone, and shale of undetermined thickness, with some coal beds, contain marine fossils, apparently rest unconformably upon the Lower Cretaceous sandstone of the Anaktuvuk group, and are probably overlain unconformably by Tertiary beds. As most of the Arctic slope is unexplored, the extent of the Upper Cretaceous rocks is not known. They are not present in the Canning River district, 100 miles east of the Colville, or along the Canadian boundary. They probably extend westward for a considerable distance and may extend as far as Cape Lisburne, nearly 400 miles west of the Colville, where the Cretaceous or Jurassic rocks of the Corwin formation are overlain by sandstone and shale that may be Upper Cretaceous.

The beds succeeding the Upper Cretaceous rocks in the Alaska Peninsula, the Matanuska Valley, the Chitina Valley, the upper Yukon district, the Rampart-Tanana district, and on the Arctic slope are Tertiary (probably Eocene) coal-bearing shale, sandstone, and conglomerate with no recognized members of marine origin, except at one locality on the Alaska Peninsula. In the Nutzotin Mountains and in southeastern Alaska, where no Upper Cretaceous rocks are known, these Tertiary deposits directly overlie the Lower Cretaceous rocks. The writer believes that there is an unconformity between the Cretaceous and the Tertiary rocks in all these districts. In several of the districts direct proof of unconformity is lacking, the Tertiary rocks not having been observed in contact with the Cretaceous rocks. The fact, however, that the Tertiary rocks rest upon other than the Cretaceous rocks which should normally underlie them is in itself an indication of unconformity at the base of the Tertiary.

CORRELATION

The probable relations of the Cretaceous rocks of the several Alaskan districts to one another and to the Cretaceous rocks of other regions is indicated in the table facing page 474.

The Lower Cretaceous rocks contain in general only a scanty marine fauna, which has not been fully studied and which does not permit precise correlations. Most of the Lower Cretaceous rocks of Alaska contain few identifiable fossils except species of *Aucella* related to *Aucella crassicollis* Keyserling and *Aucella piochii* Gabb. The Cretaceous *Aucella*-bearing beds of Alaska are believed to be approximately equivalent to the upper part of the Knoxville formation of California.

A somewhat younger horizon may be represented by the sandstone of the upper Chitina Valley, which the writer has referred to the Kennicott formation and which contains marine fossils that, according to Stanton,[11] indicate a horizon in the basal part of the Upper Cretaceous or near the top of the Lower Cretaceous. The fossil plants from the same beds, according to Knowlton,[12] are Upper Jurassic.

The Upper Cretaceous plant-bearing beds of Alaska represent two distinct horizons. Those of the Yukon Valley are low in the Upper Cretaceous, including at least the approximate horizon of the Dakota sandstone and perhaps the entire lower half of the Upper Cretaceous, and those of the Alaska Peninsula are somewhat higher in the Upper Cretaceous, possibly including the equivalent of part or all of the Montana group.

The most comprehensive section of the older plant-bearing beds is on the lower Yukon, where the rocks may be separated into four formations, of which the upper three contain floras of the same general type but specifically distinct, especially in so far as the numerous new species of angiosperms are concerned. All three formations contain species that occur elsewhere in the Dakota flora, as well as some more persistent species, notably of ferns and gymnosperms, part of which range elsewhere down into the Lower Cretaceous and Jurassic or up into the Eocene. The great thickness of these plant-bearing beds and the specific distinctness of the floras of the several formations suggest that these rocks may represent considerably more than the Dakota sandstone, possibly the entire lower half or two-thirds of the Upper Cretaceous.

The section on the lower Koyukuk, which is the northward continuation of the section on the lower Yukon, is very imperfectly

[11] Stanton, T. W., quoted by Moffit, F. H., The upper Chitina Valley, Alaska: U. S. Geol. Survey Bull. 675, pp. 37–42, 1918.

[12] Knowlton, F. H., quoted, idem, pp. 42–44.

Tentative correlation of Cretaceous rocks of Alaska

Age	Alaska Peninsula	Matanuska Valley	Chitina Valley	Nutzotin Mountains	Southeastern Alaska	Upper Yukon	Rampart-Tanana district	Lower Yukon and Nulato-Norton Bay districts	Innoko Valley	Kuskokwim Valley	Koyukuk Valley	Arctic slope	Cape Lisburne	Europe	Atlantic coast	Texas	Great Plains	Pacific States
Post-Cretaceous.	Eocene coal-bearing rocks underlain locally by Eocene tuffs.	Eocene coal-bearing rocks.	Late Tertiary to Recent lava underlain by one or more small patches of Eocene(?) coal-bearing rocks.[a]	Eocene coal-bearing rocks.[a]	Eocene coal-bearing rocks of Hamilton Bay and Kootznahoo Inlet.[a]	Eocene shale, sandstone, and conglomerate with lignite.[a]	Eocene coal-bearing rocks.[a]	Late Tertiary (?) volcanic rocks.	Tertiary (?) plant-bearing beds.		? Coal-bearing beds at Tramway Bar.	Marine Pliocene and coal-bearing (?) Eocene (?) beds.		Eocene.			Fort Union (Eocene).	
Upper Cretaceous.	Chignik formation: Upper member. Middle member. Lower member.	Matanuska formation (marine shale and sandstone).	? Conglomerate, arkose, and shale of hills near Young Center. (May be basal Eocene.) Shales of Chititu and Young creeks.			Shale and sandstone near Seventymile.	Marine Upper Cretaceous near Wolverine Mountain.	Shaktolik group (contemporaneous): Kaltag formation (coal-bearing rocks). Nulato formation (marine sandstone and shale). Melozi formation (fresh-water shale and sandstone). Ungalik conglomerate.	Shale and sandstone.	"Holiknuk series."	Bergman group (Upper Cretaceous?). Shale, sandstone, and conglomerate on the lower Koyukuk.	Nanushuk formation (position within the Upper Cretaceous not established).	Nonfossiliferous sandstone and shale, of doubtful age, overlying the Corwin formation. (May be Lower Cretaceous.)	Upper Cretaceous: Danian. Senonian. Turonian. Cenomanian.	Manasquan. Rancocas. Monmouth. Matawan. Magothy. ? Raritan.	Gulf series: Navarro. Taylor. Austin. Eagle Ford. Woodbine. Comanche series: Washita.	Lance, Laramie, and associated formations. Montana group: Fox Hills. Pierre. Colorado group: Niobrara. Benton. Dakota. Purgatoire. ?	Chico.
Lower Cretaceous.	Herendeen limestone. Staniukovich shale	Nelchina limestone. Conglomerate tuff and arkose.	Kennicott formation (sandstone and sandy shale). (?)	*Aucella*-bearing beds of Chisana and White rivers (shale and graywacke).	*Aucella*-bearing beds of Pybus Bay and Etolin Island (sandstone, shale, and conglomerate).	*Aucella*-bearing beds of Washington Creek and Charley River (slate and sandstone).	*Aucella*-bearing beds of Minook Creek (quartzite).			*Aucella*-bearing beds of "Oklune series" (sandstone and conglomerate).	*Aucella*-bearing beds of Koyukuk group (limestone, shale, sandstone, and volcanic rocks?).	*Aucella*-bearing beds of the Anaktuvuk group (sandstone, conglomerate, and shale).	Corwin formation (Cretaceous or Jurassic).	Lower Cretaceous: Albian (Gault). Aptian. Barremian. Neocomian.	Potomac group: Patapsco. Arundel. Patuxent.	? Fredericksburg. Trinity. ?		Shasta series: Horsetown. Knoxville.
Pre-Cretaceous.	Upper Jurassic.	Upper Jurassic.	Upper Triassic.	Upper Jurassic.	Upper Jurassic (?).	Upper Triassic and Paleozoic.	Paleozoic.	Paleozoic.	Paleozoic.	Late Paleozoic (?) volcanic rocks.				Jurassic.				

[a] These are the oldest post-Cretaceous rocks of the district, but they have not been observed directly overlying the Cretaceous rocks.

known and may represent either part or all of the lower Yukon section. The fossils that it has yielded are neither abundant nor distinctive. They clearly indicate the presence of floras and faunas of the general type and age of those on the lower Yukon but are not sufficient to show which of the formations of the lower Yukon section may be represented at the fossiliferous localities on the Koyukuk.

The section on the upper Yukon contains no Upper Cretaceous fossils other than plants. Its flora clearly represents that of the coal-bearing Kaltag formation of the section on the lower Yukon. The writer believes that the upper part of the Yukon Valley did not receive Upper Cretaceous sediments for a long time after the beginning of Upper Cretaceous sedimentation on the lower Yukon, and that the Upper Cretaceous sea never extended up the Yukon as far as the Seventymile district.

The Chignik formation of the Alaska Peninsula includes three members. The lower member has yielded no fossils except marine invertebrates, which according to Stanton "indicate correlation with a horizon in the Chico as developed in California and in the Nanaimo of Vancouver Island * * * but the beds at Chignik are probably not older than basal Senonian." The middle member has yielded fossil plants and a few marine mollusks, but neither the mollusks nor the plants are indicative of the precise horizon. The upper member has yielded both plants and marine invertebrates. The fauna suggests a correlation with the upper part of the Colorado group, but the flora contains elements suggestive of the Montana group.

The Upper Cretaceous fossils of the Matanuska Valley, according to Stanton,[13] "belong to the Upper Cretaceous fauna which has been recognized at several points on the Alaska Peninsula and is part of the general Indo-Pacific fauna found in the Chico formation of California, on Vancouver Island, in Japan, and in India."

The fauna of the Upper Cretaceous shale of the Chitina Valley is believed to belong at about the same horizon.

The Upper Cretaceous rocks of the Innoko and Kuskokwim valleys have yielded no fossils that are indicative of the exact horizon. The character and sequence of the rocks and their geographic position on the southern border of the Upper Cretaceous rocks of the lower Yukon suggest that they probably represent approximately the same horizon.

The fauna of the Nanushuk formation of the Anaktuvuk Valley has practically nothing in common with the other Cretaceous faunas of Alaska and can not be placed relative to them.

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[13] Stanton, T. W., quoted by Martin, G. C., and Katz, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: U. S. Geol. Survey Bull. 500, pp. 38–39. 1912.

CHRONOLOGIC RECORD

Before describing in detail the events of Cretaceous time in the area which is now Alaska, it is necessary to consider the preceding conditions that furnished the setting and, to a large extent, determined the details of the Cretaceous history.

In Pennsylvanian or early Permian time there was a widespread marine submergence, which carried the sea and spread deposits of limestone over areas in all parts of Alaska if not over the entire area. The fact that there are no extended areas in which these deposits have not been found and the absence of any known lithologic or fanual facies in the deposits indicate that the orogenic features which exist to-day and of which we find indications throughout the deposits of Mesozoic and Tertiary time probably had not been outlined before the end of the Paleozoic era.

The absence of late Permian and of Lower and Middle Triassic sediments in most if not all of Alaska indicates a pronounced withdrawal of the sea toward the end of Paleozoic time. A thick and widespread accumulation of lava, which lies between the Pennsylvanian or early Permian and the Upper Triassic sediments at many places south of the Alaska Range, but not north of it, where the Upper Triassic and Carboniferous limestones are in direct contact, indicates that the withdrawal of the sea at the end of the Paleozoic era was accompanied or closely followed by widespread volcanic outbursts throughout the region south of the present Alaska Range. These volcanic deposits are sharply limited by the present axis of the Alaska Range, a fact which indicates that the present position of the Alaska Range was determined by differential movements that began at the end of Paleozoic time.

In Upper Triassic time there was another profound marine submergence, which carried the sea into the areas of the present major mountain axes of Alaska. The restriction of Upper Triassic deposits to these mountain areas and the apparent existence, during the earlier part of the Upper Triassic epoch, of faunal facies that are characteristic of the several mountain provinces suggest that the Upper Triassic deposits were laid down in three geosynclinal basina, which occupied the sites of the present Brooks Range, Rocky Mountains, and Alaska and Coast ranges. In later Upper Triassic (Noric) time deposition was still restricted to the vicinity of the present mountains, but it was more widespread than formerly, and in the deposits then laid down there are no indications of faunal facies. At the end of the Triassic period the sea probably withdrew from the entire Alaskan area, the uppermost Triassic (Rhae-

tic) and possibly the earliest Jurassic (Lower and Middle Lias) not being represented anywhere in the Territory.

In Jurassic time there was another more or less gradual marine transgression. Lower Jurassic deposits are known only on the Pacific and Arctic seaboards. Middle Jurassic deposits have a somewhat wider extent in the Pacific coastal region. Upper Jurassic deposits are believed to have been laid down throughout the area south of the Alaska Range. The entire absence of marine Jurassic deposits north of the Alaska Range, except for some Lower Jurassic beds on the Arctic coast should be especially noted. In Jurassic time there was again a persistent shore line in or near the present position of the Alaska Range.

In Lower Cretaceous time the sea again swept over the greater part of Alaska. The submergence covered not only the site of Jurassic sedimentation south of the Alaska Range but most of the Yukon Valley, the greater part of which had been land since the end of the Paleozoic era, and much of the area of northern Alaska, from which the sea had been excluded since the end of the Triassic period. The deposits of Lower Cretaceous time generally include basal conglomerate succeeded in most places by limestone and shale that are indicative of the absence of vigorous erosion in any near-by regions. Sandy beds are present throughout the Lower Cretaceous sections in some places, notably in the vicinity of the present mountains. Volcanic rocks are notably absent in the Cretaceous of Alaska, the only apparent exceptions being the conglomeratic tuff of the Matanuska Valley, which the writer believes to be reworked Jurassic volcanic material, and the supposed Cretaceous volcanic beds of the Kuskokwim and Koyukuk Valleys, which the writer believes to be partly Carboniferous volcanic beds and partly post-Cretaceous intrusive rocks. The Lower Cretaceous faunas of Alaska consist chiefly of boreal species of *Aucella.*

At the beginning of Upper Cretaceous time the sea had receded from the Alaskan area, and when Upper Cretaceous sedimentation began it was of a different type and occurred in different areas from those of the earlier Cretaceous deposits. The major tectonic features of Alaska appear to have been well outlined by the beginning of Upper Cretaceous time, so that the distribution of the Upper Cretaceous deposits bears a very definite relation to the existing geographic features. For example, the marine Upper Cretaceous rocks do not occur along the present major mountain axes but are found for the most part on the Pacific and Arctic coasts and in the lower, broader parts of the Yukon and Kuskokwim Valleys. The Upper Cretaceous strata also include terrestrial deposits that were

laid down in embayments that were the direct predecessors of the existing major valleys.

The initial Upper Cretaceous sedimentation of Alaska may be represented by some beds of sandstone in the upper Chitina Valley which Stanton regards as either basal Upper Cretaceous or Gault but which Knowlton believes to be Jurassic.

The oldest undoubted Upper Cretaceous deposits of Alaska are found on the lower Yukon and probably extend into the Koyukuk and Kuskokwim Valleys. The stratigraphic succession on the lower Yukon includes conglomeratic beds at the base, followed in sequence by fresh-water shale and sandstone, then by marine sandstone and shale, and finally by terrestrial coal-bearing rocks which may be interbedded with a few thin marine strata. Upstream on the Yukon the full sequence outlined above is present as far as Melozi. The next exposures of Upper Cretaceous rocks are in the Rampart district, where the basal conglomerate and the fresh-water shale and sandstone are absent and marine Upper Cretaceous sandstone rests directly on the Lower Cretaceous rocks. Still farther up the Yukon, in the Seventymile district, the only Upper Cretaceous rocks are shale and sandstone which contain a flora that indicates a correlation with the upper member of the section on the lower Yukon. This correlation shows that there was a gradual submergence of the Yukon Valley in Upper Cretaceous time which permitted the younger beds to extend progressively farther up the river. The sequence of beds on the lower river, ranging from conglomerate and coarse sandstone with very few fossils at the base, through shale and sandstone with fresh-water mollusks and abundant plants, followed by marine beds, to coal-bearing rocks at the top, also indicates the gradual submergence of a large valley. The cycle began with the rapid reworking of the large volume of coarse residual detritus which had probably accumulated during the long time, possibly since the end of the Paleozoic era, during which this region had been above the sea. This process was followed by the deposition of finer detritus, which now forms the fresh-water shale and sandstone. The submergence afterward went far enough to permit the incursion of marine waters throughout the lower and middle parts of the Yukon Valley. Finally the submergence slackened, and the marshes, in which the present coal beds were formed, were permitted to spread over the surface of the marine sediments, while contemporaneous deposits now represented by plant-bearing shale and sandstone extended up the valley into areas where the Upper Cretaceous sea had never reached.

The events of Upper Cretaceous time in the Yukon region, as outlined above, probably occupied approximately the earlier half of the Upper Cretaceous epoch and the area affected not only included the

valley of the Yukon but extended north into the lower part of the Koyukuk Valley and south across the valley of the Kuskokwim nearly to Clark Lake. The Upper Cretaceous succession in the Kuskokwim Valley appears to be very closely parallel to that on the lower Yukon. Some of the Cretaceous rocks on the upper Koyukuk and on Kobuk River may mark the northern border of this province, and the Upper Cretaceous rocks of the Arctic coast, though doubtless laid down in a different basin, may date from the same time. The Upper Cretaceous rocks of the southern part of Alaska are of later date, and it is believed that while Upper Cretaceous sedimentation was in progress in the Yukon Valley the rest of Alaska was land.

During the later half of Upper Cretaceous time, when sedimentation had probably ceased in the Yukon region, the sea invaded parts of the southern coastal region of Alaska. In the Alaska Peninsula the deposits include marine shale, followed by coal-bearing shale, and then by conglomerate, sandstone, and shale that are probably of mixed marine and terrestrial origin. The sequence of events seems to have been a submergence which permitted the encroachment of the sea, a quiet period in which coal-forming marshes spread over the surface of the marine sediments, and a period of differential movement in which the marshes were submerged beneath marine waters and renewed erosion delivered large volumes of coarse gravel into the sea. The end of Cretaceous time on the Alaska Peninsula appears to have been marked by a renewal of mountain growth which finds its expression in the increasing coarseness of the youngest Cretaceous deposits. The next succeeding deposits consist of Eocene tuff, which shows that the diastrophic movements that began in late Cretaceous time afterwards culminated in volcanic outbursts. On the Alaska Peninsula, as probably everywhere else in Alaska, Cretaceous time was free from volcanism. The Upper Cretaceous deposits of the Alaska Peninsula are known near the west end of the peninsula at Chignik and Herendeen Bays and near the east end in the vicinity of Cape Douglas. It is believed that Upper Cretaceous deposits were laid down in the intervening area and removed by subsequent erosion.

The late Upper Cretaceous sea also extended into the sites of the present Matanuska and Chitina valleys, where there are shale and sandstone carrying a marine fauna that probably was approximately contemporaneous with the fauna of the lower member of the Chignik formation. The absence of Upper Cretaceous coal-bearing rocks in the Matanuska and Chitina valleys may mean either that marine conditions persisted there until the end of Cretaceous time

or that these districts were raised well above the sea while the coal-forming marshes existed on the Alaska Peninsula.

The notable absence of Upper Cretaceous rocks along most of the Pacific seaboard, especially beneath the Tertiary coal-bearing rocks on Cook Inlet, at Controller Bay, and in southeastern Alaska, may mean either that the deposition of the Upper Cretaceous rocks was restricted to a few districts, or that early Tertiary erosion removed all traces of the Upper Cretaceous rocks except in a few places where conditions were especially favorable for their preservation. There is also the possibility that the slate and graywacke of Kodiak Island, Kenai Peninsula, Prince William Sound, the Controller Bay district, Yakutat Bay, and the west coast of Chichagof Island include Upper Cretaceous rocks that have been subject, throughout their entire linear extent, to folding and metamorphism that were much more intense than those which affected either the rocks on the margin of the belt of slate and graywacke or the Upper Cretaceous rocks of neighboring districts.

Upper Cretaceous time ended with the complete withdrawal of the sea from the Alaskan area and probably was closely followed by the folding and erosion of the Cretaceous rocks. The Cretaceous rocks of Alaska are highly folded almost everywhere, and many of them are cut by intrusive rocks and by metalliferous veins. In many places it is not possible to determine the exact date of the folding, intrusion, and mineralization, especially as some of the Tertiary rocks have been similarly affected. It is believed, however, that at least part of the folding, intrusion, and mineralization dates from about the end of Cretaceous time. The earliest post-Cretaceous rocks in most of Alaska are the widespread Tertiary coal-bearing beds. Although these rocks are highly folded in some places and have been cut by dikes and veins, they are in general notably less indurated, folded, and altered than the Cretaceous rocks. In some places there is clear proof of an unconformity at the base of the Tertiary rocks, and the writer believes that the Cretaceous rocks of Alaska were subjected to uplift and erosion, if not folding, immediately at the end of Cretaceous time in all parts of the Territory.

ROCKS OF UNDETERMINED AGE, MESOZOIC OR OLDER

SLATE, GRAYWACKE, AND GREENSTONE OF THE PACIFIC COAST

GENERAL FEATURES

The slate and associated rocks, including graywacke, in some places phyllite, and both intrusive and bedded volcanic rocks, usually described as greenstone, that occur at scattered localities

along the Pacific coast from Sitka to Kodiak offer a complex and difficult series of problems in correlation and in determination of age. These problems have not been indisputably settled at any one point, and taken as a whole they constitute one of the most inviting fields of broad correlative study that still remain unworked in Alaska.

These rocks cover large areas along much of the Pacific shore north of latitude 57°, bordering the Gulf of Alaska for 800 miles and extending inland in places as far as the Alaska Range. The slaty rocks of this belt resemble one another in composition, in degree of metamorphism, in the general absence of characteristic fossils, and in the different structural and correlative problems which they present. They differ from one another sufficiently to have been subdivided into several formations in some of the districts, to have been designated by one or more new formation names by most of the earlier observers, and to have been assigned to every geologic period from the Silurian to the Pleistocene.

It is obviously impossible to place these rocks among the undoubted Mesozoic strata that have been described in the preceding chapters. Brief references to the principal descriptions of the rocks in each of the districts will be given, followed by a statement of the writer's opinion on their age.

LOCAL DESCRIPTIONS

SLATE AND GRAYWACKE OF KODIAK ISLAND

Parts of Kodiak and the neighboring islands contain slate and graywacke of undetermined age. These rocks were described by Dall,[14] who considered them older than the Middle and Upper Jurassic rocks which he had seen on the mainland of Alaska and who accepted their provisional reference to the Triassic on the basis of Hyatt's identification of the fossils which Dall collected.[15] These rocks have been described briefly by Emerson,[16] Martin,[17] and Maddren,[18] and their fossils have been described by Ulrich,[19]

[14] Dall, W. H., Report on coal and lignite of Alaska: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 1, pp. 871–872, 1896.

[15] Hyatt, Alpheus, Report of the Mesozoic fossils (appendix to Dall's Report on coal and lignite of Alaska): Idem, p. 907.

[16] Emerson, B. K., General geology; Notes on the stratigraphy and igneous rocks: Alaska, vol. 4, pp. 51–53, Harriman Alaska Expedition, 1904.

[17] Martin, G. C., Mineral deposits of Kodiak and neighboring islands: U. S. Geol. Survey Bull. 542, pp. 128–129, 1913.

[18] Maddren, A. G., The beach placers of the west coast of Kodiak Island: U. S. Geol. Survey Bull. 692, pp. 301–302, 1919.

[19] Ulrich, E. O., Fossils and age of the Yakutat formation: Alaska, vol. 4, pp. 125–146. Harriman Alaska Expedition, 1904.

who referred them to the Lower Jurassic. Ulrich described the following fossils from the deposits near Kodiak:

Terebellina palachei Ulrich.
Inoceramya concentrica Ulrich.
Chondrites divaricatus Fischer-Ooster.
Chondrites alpestris Heer.
Palaeodictyon magnum laxum Ulrich.
Palaeodictyon singulare Heer.
Arthrodendron diffusum Ulrich.
Cancellophycus rhombicum Ulrich.
Retiphycus hexagonale Ulrich.
Gyrodendron emersoni Ulrich.
Gilbertina spiralis Ulrich.
Helminthoida exacta Ulrich.
Helminthoida subcrassa Ulrich.
Helminthoida abnormis Ulrich.
Helminthoida vaga Ulrich.
Helminthopsis magna Heer.
Helminthopsis? labyrinthica Heer.
Myelophycus cunatum Ulrich.

SUNRISE GROUP

The slate and graywacke of Kenai Peninsula have been generally described as the Sunrise group. The latest and most comprehensive descriptions are those by Martin,[20] Johnson,[21] and Grant.[22] The following description by Martin[23] contains reference to previous descriptions:

Slates and graywackes compose the greater part of the Kenai Mountains, the only other known rocks they contain being intrusive masses, which are most abundant on the southern and eastern coasts, the greenstones near Resurrection Bay, the volcanic beds interstratified with the slate and graywacke in the western part of the peninsula, and the Mesozoic and other sediments that compose the foothills along the southern shore of Kachemak Bay.

These rocks have been mapped as a unit in the northern and central parts and along the western front of the Kenai Mountains, but on the southern coast of the peninsula Grant has recognized four formations, each composed partly of slates and graywackes but differing in degree of metamorphism and to some extent in composition. The writer believes that most or all of these formations extend into other parts of the Kenai Mountains where the rocks were mapped as a unit, not because of their lithologic homogeneity but because the field work was not sufficiently detailed to justify the mapping of the subdivisions. The slaty rocks of Kenai Peninsula are not a lithologic unit of uniform stratigraphic character but constitute a stratigraphic and structural complex containing rocks of moderately diverse lithologic character and probably of widely differing ages.

The slate and graywacke of Seldovia Bay underlie the ellipsoidal basalts, which in turn apparently lie beneath the presumably Upper Triassic cherts. They are consequently either Paleozoic or early Triassic. The slates and graywackes in the vicinity of Turnagain Arm contain fossils which are apparently either Jurassic or Cretaceous. This locality is within the type district of the Sunrise group as described by Mendenhall[24] and by Moffit,[25]

[20] Martin, G. C., General features of Kenai Peninsula: U. S. Geol. Survey Bull. 587, 1915, pp. 33–35; The western part of Kenai Peninsula: Idem, pp. 44–52.

[21] Johnson, B. L., The central and northern parts of Kenai Peninsula: Idem, pp. 113–119.

[22] Grant, U. S., The southeastern coast of Kenai Peninsula: Idem, pp. 211–227.

[23] Idem, pp. 33–35.

[24] Mendenhall, W. C., A reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 305–307, 1900.

[25] Moffit, F. H., Gold fields of the Turnagain Arm region: U. S. Geol. Survey Bull. 277, pp. 17–19, 1906.

which has been generally regarded as the probable equivalent of the Valdez group[26] and has been generally assigned to the Paleozoic.[27] The slaty rocks on the south coast of the peninsula include slates and graywackes consisting of two probably unconformable members, occurring from Day Harbor to Nuka Island Passage, regarded by Grant as the equivalent of the Sunrise group; slate and graywacke in relatively small volume associated with greenstones, occurring on Day Harbor and the east shore of Resurrection Bay, regarded by Grant as the equivalent of the Orca group of Prince William Sound; slate, graywacke, and conglomerate, less altered than the rocks regarded by Grant as equivalent to the Sunrise group, occurring on the forelands from Nuka Island Passage to Chugach Bay; and graywacke and slate, associated with cherts, limestones, and basic igneous rocks, occurring on the bays from Nuka Island Passage to Port Chatham, and apparently the direct areal extension of the slate and graywacke of Port Graham and Seldovia Bay.

The evidence of the age of these slaty rocks indicates that the type area of the Sunrise group contains beds that are middle or late Mesozoic, possibly as young as Upper Cretaceous, whereas the slates of the southern part of the district are probably Paleozoic, certainly not being younger than Triassic. The data now available afford no grounds for separating these rocks, either cartographically or by description, so that the term Sunrise group can not be used at present for a lesser aggregate than all the slaty rocks of the Kenai Peninsula. The Sunrise group, in such a usage of the term, therefore doubtless includes beds which are equivalent to the Valdez group of Prince William Sound. The correlation of the Sunrise and Valdez as exact equivalents is, however, of very doubtful validity. As the rocks of the type district of the Sunrise group are probably high rather than low in the stratigraphic sequence of rocks in the Kenai Mountains, and as the Valdez group is generally regarded as including the older rather than the younger slaty rocks of Prince William Sound, it seems probable that if the slates of the Kenai Mountains and of Prince William Sound are in general equivalent, as they are supposed to be, then the rocks of the type area of the Sunrise group on Turnagain Arm and vicinity are probably more nearly equivalent to the slates of the Orca group than to those of the Valdez group. The equivalent of the Valdez group is probably to be sought in the unfossiliferous pre-Triassic slates south of Kachemak Bay or in the more altered lower member of the slates on the coast from Resurrection Bay to Nuka Island rather than in the fossiliferous Jurassic or Cretaceous slates in the vicinity of Turnagain Arm. It should be noted that the fossils which were obtained at Nuka Bay from the upper member of the slates and graywackes that extend from Resurrection Bay to Nuka Island are identical with the fossils collected by the writer on Kenai Lake, and that these fossils occur on Prince William Sound in the Orca and not in the Valdez group.

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[26] Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna Basins, Alaska: U. S. Geol. Survey Bull. 327, pp. 15–16, 1907.

[27] Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, p. 24, 1911.

VALDEZ AND ORCA GROUPS

The slate, graywacke, and greenstone of Prince William Sound have been described [28] as the Valdez and Orca groups, which are supposed to include all the sedimentary and metamorphic rocks of Prince William Sound. The Valdez group has been generally regarded as underlying the Orca group and as being probably Paleozoic, whereas the Orca group has been generally regarded as probably Mesozoic. The relative sequence of the Valdez and Orca groups is somewhat in doubt, and even the validity of their differentiation has been questioned. As to their age, there is very little evidence on which a positive opinion can be based. The only fossils that have been found on Prince William Sound, which came from various undetermined positions in the Valdez-Orca sequence, are fucoids and worm tubes like those of the Yakutat group and the slate and graywacke of Kodiak Island, indeterminate fragments of plants, crinoid remains [29] that suggest the "Cretaceous or later," and cephalopods [30] that apparently are early Paleozoic.

SLATE AND GRAYWACKE OF SUSITNA VALLEY

Slate, graywacke, and conglomerate of undetermined age have been found in various parts of the upper Susitna Valley. These rocks include the "Susitna slates" described by Eldridge,[31] the "slates and schists of the Susitna and Talkeetna Valleys" [32] and the "undifferentiated Paleozoic rocks in the headwater region of the Susitna" [33] described by Brooks, the "Jurassic (?) rocks" [34] and the "undifferentiated Mesozoic (?) rocks" [35] of the Broad Pass region described by Moffit, the "argillites, slates, and graywackes" of the

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[28] Schrader, F. C., A reconnaissance of Prince William Sound and the Copper River district, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 404–408, 1900. Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska (U. S. Geol. Survey special publication), pp. 34–40, 1901. Grant, U. S., and Higgins, D. F., Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: U. S. Geol. Survey Bull. 443, pp. 22–23, 1910. Capps, S. R., General geology [of the Ellamar district]: U. S. Geol. Survey Bull. 605, pp. 30–46, 1915. Johnson, B. L., Copper deposits of the Latouche and Knight Island districts, Prince William Sound: U. S. Geol. Survey Bull. 662, pp. 197–200, 1918; Mineral resources of the Jack Bay district and vicinity, Prince William Sound: U. S. Geol. Survey Bull. 692, pp. 158–163, 1919.

[29] Johnson, B. L., op. cit. (Bull. 662), p. 198.

[30] Moffit, F. H., unpublished report.

[31] Eldridge, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: U. S. Geol. Survey Twentieth Ann. Rept., pt. 7, pp. 15–16, 1900.

[32] Brooks, A. H., The Mount McKinley region, Alaska: U. S. Geol. Survey Prof. Paper 70, p. 65, 1911.

[33] Idem, pp. 68–69.

[34] Moffit, F. H., The Broad Pass region, Alaska: U. S. Geol. Survey Bull. 608, pp. 32–38, 1915.

[35] Idem, pp. 39–40.

Chulitna Valley described by Capps,[36] and the "slate and graywacke series" of the Kahiltna Valley described by Mertie.[37]

The only evidence on the age of the slate and graywacke of Susitna Valley is yielded by some specimens of *Inoceramus* that are suggestive of Upper Cretaceous age (see pp. 309–310) and by some fossils collected by R. M. Overbeck in 1919, concerning which T. W. Stanton [38] has submitted the following statement:

10240 (Fl). Ridge west of Portage Creek, Eakin's station sub. 9, Susitna Valley. These fragments of slate show no fossils except a number of slender tubular bodies which resemble small specimens of *Terebellina palachei* Ulrich, a species from the Yakutat group whose definite place in the Alaskan stratigraphic column is still unknown, though it was believed by Ulrich to be Lower Jurassic.

SLATE OF CONTROLLER BAY

The metamorphic rocks of the Controller Bay region crop out on Wingham Island and in Ragged Mountain west of Katalla. The rocks consist [39] of black slate having a well-developed cleavage, of graywacke, of a variety of highly colored fine-grained rocks of uncertain origin, and of greenstone and other rocks of igneous origin which probably include both bedded and intrusive masses. The only fossils that have been discovered are numerous but poorly preserved specimens of *Globigerina* of indeterminate species. The rocks of both areas are overthrust upon Tertiary shale. The degree of metamorphism shows the rocks to be pre-Miocene, and the occurrence of *Globigerina* (assuming that the lower range of *Globigerina* has been finally determined) shows them to be post-Carboniferous. More definite evidence of their age is lacking.

YAKUTAT GROUP

The rocks of the Yakutat group have been described by Russell,[40] Novarese,[41] Tarr and Butler,[42] and Blackwelder.[43]

[36] Capps, S. R., Mineral resources of the upper Chulitna region: U. S. Geol. Survey Bull. 692, pp. 217–218, 1919.

[37] Mertie, J. B., jr., Platinum-bearing gold placers of the Kahiltna Valley: U. S. Geol. Survey Bull. 692, pp. 236–237, 1919.

[38] Personal communication.

[39] Martin, G. C., Geology and mineral resources of the Controller Bay region, Alaska: U. S. Geol. Survey Bull. 335, pp. 26–27, 1908.

[40] Russell, I. C., An expedition to Mount St. Elias: Nat. Geog. Mag., vol. 3, pp. 130–131, 140, 167, 170, 1890; Second expedition to Mount St. Elias, in 1891; U. S. Geol. Survey Thirteenth Ann. Rept. pt. 2, pp. 24–26, 34, 52, 90, 1893.

[41] Novarese, I. V.. Rocks and minerals of South Alaska: The ascent of Mount St. Elias, Appendix E, pp. 232–239, 1900.

[42] Tarr, R. S., and Butler, B. S. Areal geology [of the Yakutat Bay region]: U. S. Geol. Survey Prof. Paper 64, pp. 152–160, 1909.

[43] Blackwelder, Eliot, Reconnaissance on the Pacific coast from Yakutat to Alsek River: U. S. Geol. Survey Bull. 314, pp. 82–87, 1907.

The Yakutat "system" was described by Russell as consisting of gray and brown sandstone and nearly black shale or slate.

Tarr and Butler described it as a complexly folded and faulted series of rocks in which the three most prominent elements are (1) a series of thinly bedded black shale and gray sandstone, (2) a black shale conglomerate, with crystalline pebbles and boulders, and (3) a massive crystalline rock, the most prominent rock in the Yakutat group, which was tentatively classed as an indurated tuff. The Yakutat group is of unknown thickness, its relation to the adjoining rocks has not been satisfactorily determined, and it has yielded no fossils, except the supposed worm tube *Terebellina palachei* Ulrich and a supposed irregular echinoid which Stanton[44] believes to be post-Triassic.

The Yakutat group was divided by Blackwelder into an upper member consisting of graywacke, conglomerate, and hard black shale, and a lower member consisting of black shale conglomerate of possible glacial origin.

AGE

Fossils have been found in the slate and graywacke of the Pacific coast of Alaska in the vicinity of Kodiak, at several places on Prince William Sound, and near Yakutat. The fossils from Kodiak consist of 16 species of fucoids, a pelecypod, and a supposed worm tube.

Of the 16 fucoids, 10 are new species and are known only from this locality, 2 species are known also from the European Eocene, and 4 are restricted to the Lower Jurassic of the Alps. On this evidence Ulrich considers the Lower Jurassic age of the rocks as proved.

The pelecypod was described as a new genus and species *Inoceramya concentrica*, known from this one locality. Ulrich assumed the genus to be the ancestor of *Inoceramus*, which he stated to be a "characteristic Cretaceous genus," and hence assumed the ancestor to prove the Jurassic age of the rocks containing it. But inasmuch as *Inoceramus* was well developed in the Jurassic, then the ancestor (if it is an ancestor) proves its terrain to be pre-Jurassic. Both the origin and the validity of the genus are in doubt. Specimens of *Inoceramus* from the Upper Cretaceous of Alaska are very similar to *Inoceramus concentrica*.

The supposed worm tube is a new genus and species which is restricted to Alaska but which is known not only from Kodiak but also from Yakutat, Prince William Sound, and other places. The

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[44] Stanton, T. W., cited by Tarr, R. S., and Butler, B. S., op. cit., p. 158.

worm furnishes no evidence as to its absolute age and no satisfactory evidence as to the correlation of the rocks containing it.

The slate and graywacke of the Pacific coast of Alaska have been generally assigned to the Mesozoic, chiefly because of Ulrich's opinion concerning the fossils from Kodiak, but the writer believes that the evidence of these fossils is insufficient for a positive determination of age and is capable of a different interpretation from that which Ulrich placed upon it. Ulrich's conclusion from the evidence of the fucoids was based on the assumption[45] "that we are not dealing with the new horizon" and that "the slate of Kodiak must be referred to either the Lower Jurassic (Lias) or to the Eocene."

The writer believes that there is no basis for the assumption that the fucoids from Kodiak can not represent a "new horizon." In the immediately preceding sentence Ulrich himself cited the discovery of "new horizons" for a supposed Eocene fucoid in the Carboniferous and possibly in the Silurian. The writer is not influenced as much by Ulrich's final conclusion as he is by Ulrich's statements[46] that the evidence from the genera of fucoids "points perhaps quite as strongly to the Eocene as to the Lias" and that

> we have seen black inosculating films in the Waverly shales of Kentucky and certain Carboniferous shales in Texas that we are really at a loss to distinguish from the Eocene species figured by Heer or from the Kodiak species.

The entire absence of any of these fossils in the richly fossiliferous Mesozoic beds of this region; the stratigraphic dissimilarity of the slate and graywacke to most of the undoubted Mesozoic strata, especially to those of the Jurassic and Triassic; the greater degree of alteration of the slate and graywacke as compared with that of the undobuted Mesozoic rocks; the absence of any known Paleozoic rocks in most of this region; and the position of the slate and graywacke of Seldovia Bay beneath the greenstone that underlies the fossiliferous Triassic and Lower Jurassic beds (see pp. 45–46) all suggest the Paleozoic age of the slate and graywacke.

There are doubtless some Mesozoic beds, probably chiefly of Cretaceous age, occurring within the area of the slate and graywacke, but the writer suspects that such Mesozoic rocks may represent small structural inclusions in a larger mass of early Paleozoic strata.

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[45] Ulrich, E. O., Fossils and age of the Yakutat formation: Alaska, vol. 4, pp. 129–130, Harriman Alaska Expedition, 1904.

[46] Idem, pp. 130, 131.

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