IN REPLY REFER TO:

Geol.-Alas:GMF,Jr

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

May 15, 1953

Mr. P. R. Holdsworth
Commissioner of Mines
Territory of Alaska
P. O. Box 2811
Juneau, Alaska

Enclosed herewith is a copy of the report, "Correlation of the Cretaceous Formations of Greenland and Alaska", by Ralph W. Imlay and John B. Reeside, Jr to be placed on open file in your office. A copy of the press statement announcing the release date, which we anticipate will be May 18 or 19, will be forwarded to you as soon as it is received by us. Please do not place the report on public inspection until you obtain the release date.

Sincerely yours,

George M. Flint, Jr
Geologist-in-Charge
Washington Office
Alaskan Geology Branch

Copies to :
George O. Gates
Ludlow G. Anderson
Leo H. Saarela
P. R. Holdsworth
Robert M. Chapman
C. L. Sainsbury
Miss Mary P. Smith

Flint -- Int. 3717

DEPARTMENT OF THE INTERIOR

INFORMATION SERVICE

GEOLOGICAL SURVEY

For Release to PM's, MAY 18, 1953

CORRELATION OF THE CRETACEOUS FORMATIONS OF GREENLAND AND ALASKA

A report and illustrations on the correlation of the Cretaceous formations of Greenland and Alaska by R. W. Imlay and J. B. Reeside, Jr., geologists of the Geological Survey, are being placed on open file for public inspection today, Secretary of the Interior Douglas McKay announced today.

Correlation of the Alaskan Cretaceous fossils is based on a comprehensive restudy of the Cretaceous collections that have been made by the Geological Survey in the Territory. The first such collections were made late in the 19th century and have been added to intermittently during the intervening years. As individual collections were obtained, they were examined and reports prepared for use in Survey publications. The present study is primarily a reinterpretation of the age significance of all these fossil collections by comparing them with Cretaceous fossils obtained in parts of North America where the stratigraphic and faunal succession is much better known than in Alaska. Consideration is also given to stratigraphic and lithologic criteria, particularly in areas where fossil evidence is scant. Sections of Cretaceous rocks in the Matanuska Valley, in the southwestern part of the Copper River region, and in northern Alaska north of the Brooks Range, have been examined. All the information has been incorporated in stratigraphic summaries which should be useful to field geologists regardless of their background in paleontology.

The reexamination was initiated primarily for purely scientific reasons, but as progress of the project continued its immediate economic applicability became increasingly apparent. The material is now being placed on open file prior to final publication because of the increased public interest in Alaska's petroleum possibilities and the part that this material can play in serving that interest.

The report is on file in the offices of the Geological Survey, Room 1033 (Library) and Room 4224 (Alaskan Geology Branch), GSA Building, Washington, D. C.; Room 100, Old Mint Building, San Francisco, California; Mines Building, College, Alaska; Subport Building, Juneau, Alaska; Central Building, Anchorage, Alaska, and at the Territorial Department of Mines at Juneau, Alaska. For persons directly interested, a limited number of mimeographed copies are available free upon application to the Director, Geological Survey, Washington 25, D. C.

x x x

P.N. 41561

CORRELATION OF THE CRETACEOUS FORMATIONS OF GREENLAND AND ALASKA [1/]

by

Ralph W. Imlay and John B. Reeside, Jr. [2/]

CONTENTS

ILLUSTRATIONS

1/ Publication authorized by the Director, U. S. Geological Survey

2/ U. S. Geological Survey, Washington, D. C.

INTRODUCTION

This is Number 10d of a series of correlation charts prepared for the Committee on Stratigraphy of the National Research Council. 3/ It has been sponsored by the U. S. Geological Survey

---

3/ Dunbar, C. O., et al. (1942) Correlation charts prepared by the Committee on Stratigraphy of the National Research Council, Geol. Soc. Am., Bull., vol. 53, p. 429-434.

---

and has required about seven months' time of both authors gathering and compiling data and evaluating fossil evidence. As the two regions dealt with in the chart are widely separated, the lists of references are also given separately. The annotations dealing with Greenland are based entirely on published information. The annotations dealing with Alaska are based on a re-examination of nearly all the Cretaceous fossils from Alaska in the collections of the Geological Survey. This has resulted in many concepts not hitherto published and in some concepts that are completely at variance with those that have been published. Naturally for large areas undergoing active exploration, such as Alaska, a correlation chart is out of date in many particulars as soon as published. Nevertheless it is valuable to the field man whose activities are confined to small areas but who must interpret much of his data in terms of surrounding areas that he has not seen. It is valuable to the student and to the general geologist because it organizes scattered information in a manner that can be applied in their field problems, makes quite unnecessary the memorization of stratigraphic sections and fossil names, and shows clearly that stratigraphic correlations are based on observation and reasoning and not on a vast memory. It is probably of greatest value to the specialist who makes the chart because he discovers what areas and problems are most in need of research and can thereby direct his efforts and those of his associates in a manner that will yield the greatest results.

ANNOTATIONS

1. In eastern Greenland (Fig. 1) the Aptian and Albian stages of the Lower Cretaceous are represented mostly by black to gray shale containing orange to red weathering concretions or thin beds of clay ironstone. Some sections contain intercalations of light yellow marl and yellow to brown siltstone, sandstone, or conglomerate. Sandstone dominates in the Aptian part of the sequence on Koldewey Island and on the northwestern part of Hold-with-Hope and is locally common in the Albian. In a few places occur enormous angular blocks that are interpreted as landslide material derived from fault scarps bordering the sea. The base of the sequence rests on an irregular surface composed of basal Cretaceous, Jurassic, Triassic, Permian, or older rocks. Locally in the Falskebugt area of eastern Wollaston Foreland, the Aptian rests on the Valanginian beds with angular discordance of about 24 degrees. The thickness of the sequence is estimated to be more than 2000 meters (Maync, 1949, pp. 195-211).

The record of Aptian in East Greenland is based mainly on the occurrence of the ammonites Deshayesites, Sanmartinoceras, Ancyloceras, and Tropaeum (Bogvad and Rosenkrantz, 1934; Frebold, 1935; Spath, 1946). On the basis of published studies in England and France (Spath, 1930; Roch, 1927; Kilian and Reboul, 1915), Ancyloceras is characteristic of the lower Aptian and is rare in the Barremian, Deshayesites is characteristic of the upper part of the lower Aptian but ranges into the lower part of the upper Aptian, and Tropaeum ranges from the upper part of the lower Aptian into the lower part of the upper Aptian. The genus Sanmartinoceras was considered by Whitehouse (1926, p. 204) to be restricted to the uppermost Aptian on the basis of occurrences in Australia. He considered the records from the lower Aptian of Germany to be in error. However, in the middle of the Cogollo formation in Sierra de Perijá, Venezuela, Sanmartinoceras is associated with Colombiceras, Deshayesites, and Cheloniceras aff. C. cornuelianum (D'Orbigny). As Colombiceras has not been found below the upper Aptian, this association probably represents the base of the upper Aptian rather than any part of the lower Aptian, provided that the ammonites were all obtained from the same bed. It may be significant that Sanmartinoceras has not been found in the highest Aptian beds of Mexico (Humphrey, 1949), Colombia (Riedel, 1937), or Venezuela in association with Dufrenoya justinae (Hill). On the basis of the ammonites collected in Greenland only part of the lower Aptian has been definitely identified, but part of the upper Aptian may be represented by Tropaeum and Sanmartinoceras. Neither the very earliest or latest Aptian has been identified faunally in Greenland.

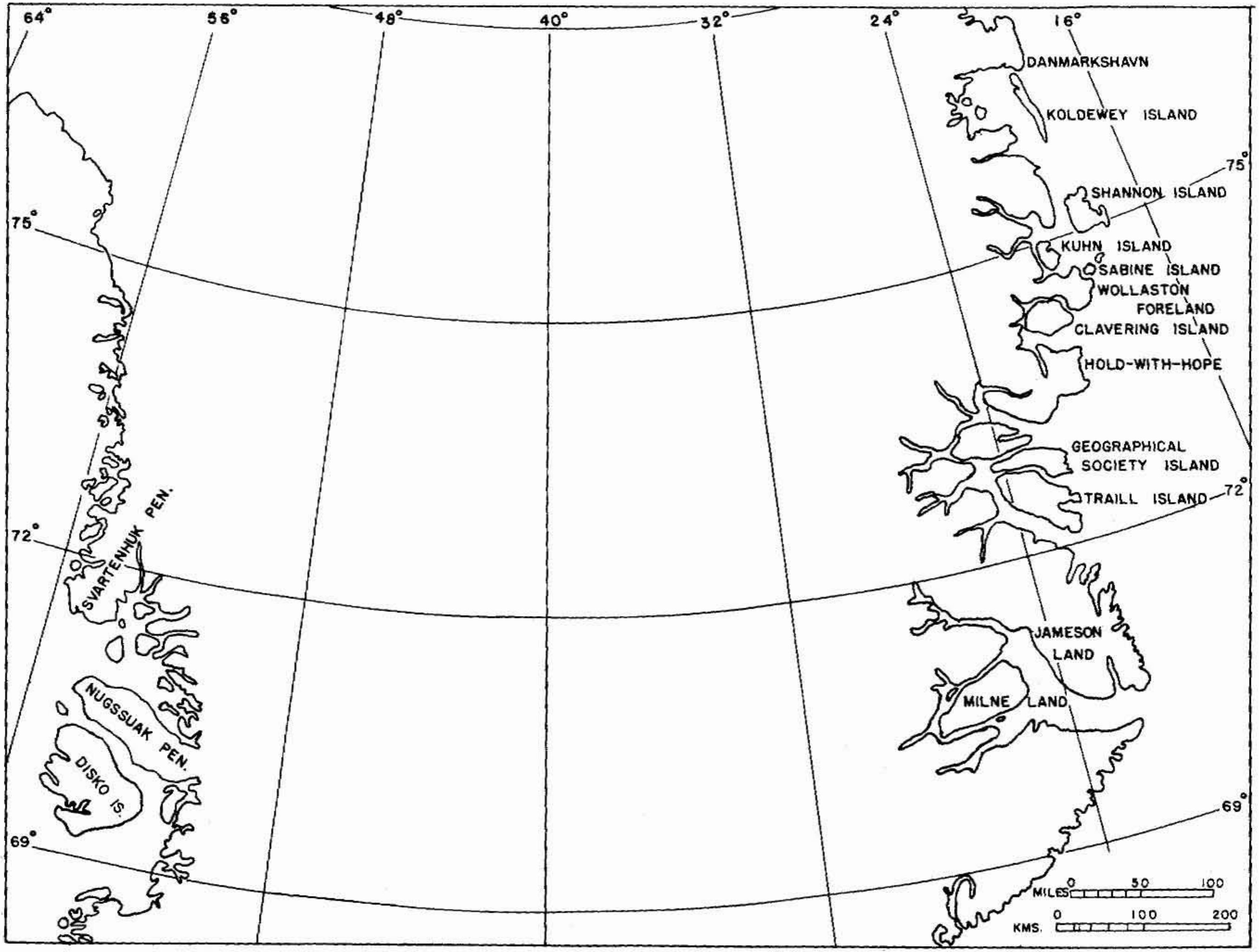

FIGURE 1. - INDEX MAP OF GREENLAND

40228

The lower and middle Albian are represented in East Greenland, according to Spath (1946, pp. 8-10), by several ammonite assemblages, whereas there is a lack of any typical upper Albian ammonites. However, some impressions referred questionably to Gastroplites by Spath may represent the lower part of the upper Albian, even though the only accurately dated occurrences of the genus are in the middle Albian in England (Spath, 1937, p. 257), in California, and in Alaska (see Annotations 14, 31, 46). This possibility is based on the presence of Gastroplites in the lower part of the Mowry shale in the western interior of the United States (Cobban and Reeside, 1951, pp. 1892, 1893; Cobban, 1951, p. 2179). This shale on the basis of stratigraphic position represents some part of the upper Albian, because it directly underlies the Belle Fourche shale, which contains Cenomanian faunas, and it occurs a short interval above the Skull Creek shale which is correlated faunally with both the Duck Creek limestone and the Kiamichi formation of Texas and with the Purgatoire formation of northeastern New Mexico (Reeside, 1923, p. 200). Both the Duck Creek limestone and the upper part of the Purgatoire formation have furnished ammonites representing the basal upper Albian. It is probably of stratigraphic significance that the species of Gastroplites in the Mowry shale are considerably different from the genotype species, G. canadensis (Whiteaves), and may eventually be placed in a distinct genus.

It seems probable that the age of the upper part of the Aptian and Albian sequence in East Greenland varies from one locality to another owing to erosion before deposition of the capping basalts and sediments of early Tertiary age. However, the amount of erosion has not been ascertained and may not be determinable owing to scarcity of fossils. For the purposes of the chart, it is assumed that the upper part of the sequence in each general area corresponds to the boundary between the middle and upper Albian.

2. The Berriasian (used in same sense as Infravalanginian) has been found in East Greenland only in two areas, which are (1) the Scoresby Sound district and (2) southwestern Kuhn Island and the nearby northwestern part of Wollaston Foreland. Its absence elsewhere in East Greenland is explained partly by pre-Aptian erosion and partly by nondeposition.

In the Scoresby Sound district the main occurrence is in southern Jameson Land (Aldinger, 1935, p. 38; Spath, 1947, p. 49), where ammonites were obtained in the upper part of about 500 feet of dark sandy shale and soft, thin sandstone and in a shelly bed at the base of the overlying 330 feet of cross-bedded sandstone. These ammonites were placed by Spath (1947, pp. 53-57) in Subcraspedites and a new genus Hectoroceras and were considered by him as probably earliest Cretaceous rather than latest Jurassic.

In the area comprising southwestern Kuhn Island and adjoining parts of Wollaston Foreland, the Cretaceous section (Maync, 1949, pp. 27-32, 96-100, 183) begins with 100 meters of banded sandstone and shale containing large boulders. The highest boulder bed, about 30 feet below the top, contains two Subcraspedites that Spath (1946, p. 4; 1947, p. 58) considers to be Cretaceous. These are associated with ammonites that are reported to be reworked from Jurassic strata. Next above follows 40 meters of gray to reddish sandstone and sandy limestone that contain craspeditid ammonites, including one specimen that Spath refers questionably to Hectoroceras (Spath, 1947, p. 58, pl. 3, fig. 2). Above this follows beds 55 meters thick that include gray sandy shale interbedded with hard limestone, a covered interval, and then some sandy limestone. This is succeeded by 75 meters of red to brown sandy shale and interbedded sandy limestone. Ten meters below the top of this unit was obtained one specimen of the ammonite Tollia which is characteristic of the Berriassian (Infra-Valanginian) in northern Siberia and Novaya Zemlya.

3. The middle Valanginian exists in two contrasting facies that grade into each other laterally and at places vertically (Maync, 1949, pp. 185-192). The Albrechts Bay facies, named from northcentral Wollaston Foreland, consists of gray, yellow, or pink marl and marly shale containing limestone beds and nodules. The Young Sound facies consists of coarse breccias and conglomerates, locally unstratified and unsorted, embedded in a matrix of sandstone and including lumps and lenses of gray or yellow limestone that bear numerous aucellas. This facies, which Maync interprets as forming at the base of fault scarps, passes upward in some sections in central Wollaston Foreland into gray to yellow, partly sandy limestone. The Falskebugt beds in eastern Wollaston Foreland display a similar mixed facies. The assignment of a middle Valanginian age to these beds is based on such ammonites as Polyptychites, Euryptychites, Dichotomites and Neocraspedites. There is no faunal evidence for the presence of lower Valanginian, and judging by the sections in northern Wollaston Foreland, there are only a few meters of red-brown sandstone that might represent the lower Valanginian.

4. The upper Valanginian in eastern Kuhn Island and in most of Wollaston Foreland is represented by 15 meters or less of red sandstone, breccias, and locally marl and coquinoid limestone which Maync (1949, pp. 70-72, 192) has named the Rødryggen beds. Somewhat similar red beds in northwestern Wollaston Foreland have furnished a single specimen of Lyticoceras (Maync, 1949, p. 98), which Spath (1946, p. 6) considers is probably upper Valanginian rather than lower Hauterivian.

5. From 90 to 450 feet of light-gray, micaceous sandstone and dark-gray, brittle sandy shale exposed near Knudshoved on the eastern coast of Hold-with-Hope have furnished pelecypods that Frebold (1934, pp. 9-27) identifies with Pteria tenuicostata Roemer and Inoceramus similar to I. cardissoides Goldfuss and considers to be of late Emscherian age, which is early Santonian as used herein. Frebold (1934, p. 21) also made the same age assignment for a specimen of Pteria tenuicostata Roemer from Home Foreland at the northeast end of Hold-with-Hope. However, Maync (1949, pp. 136, 137, 212-214) examined the sequence at Home Foreland and concluded that it belonged lithologically and faunally with the Aptian and Albian sequence. He did not find a single specimen of Pteria at Home Foreland and suggests the possibility of mislabeling of the specimen reported from there. He notes that Andreas Vischer (Maync, 1949, p. 144) at a locality 2 kilometers south of Knudshoved found the light-colored sandy Knudshoved beds marked basally by a thin conglomerate that rests on dark-colored marly beds such as are exposed widely at Home Foreland. Maync (1949, p. 215, 217) concludes that exposures of the Upper Cretaceous strata of Santonian age are confined to the vicinity of Knudshoved.

6. Spath (1946, p. 10) has identified the lower Cenomanian ammonite Schloenbachia in collections from Traill Island and the southern part of Geographical Society Island (Stauber, 1938, Donovan, 1949, p. 8). He, also, identified the Turonian ammonites Scaphites aff. S. lamberti (de Grossouvre) and Prionotropis cf. P. woolgari (Mantell) (equals Collignoniceras woolgari). These indicate the lower part of the upper Turonian.

7. Marine shale cropping out on the north shore of the Nugssuak Peninsula in West Greenland have furnished ammonites and pelecypods representing the Coniacian to Maestrichtian stages of the Upper Cretaceous (Loriol, 1893; Madsen, 1897; Ravn, 1918, p. 309; Frebold, 1934, pp. 25-27). The presence of the Turonian stage has not been proven. The Coniacian is represented by Scaphites similar to S. ventricosus Meek and Hayden (Rosenkrantz, 1942, p. 39, pl. 1). The Maestrichtian is represented by ammonites referred variously to Acanthoscaphites roemeri (d'Orbigny) and Discoscaphites nicolleti (Morton). A number of pelecypods listed by Ravn (1918) from West Greenland occur in the western interior of the United States in beds of Campanian to Maestrichtian age (White and Schuchert, 1898, pp. 356, 357).

8. The Patoot beds in the southern part of the Nugssuak Peninsula have furnished a flora regarded as of latest Cretaceous age (Heer, 1883; Ravn, 1918) and at Patoot have furnished species of Inoceramus that in Europe are reported to be restricted to the upper Santonian (Heinz, 1928; Maync, 1949, p. 279). The age limits of the Patoot beds are not known. It is possible that they are entirely of Santonian age.

9. The Atane beds carry a dicotyledonous flora that was once considered to be of Senonian age (Heer, 1883; Ravn, 1918). However, they are overlain by marine shales carrying Scaphites similar to Scaphites ventricosus Meek and Hayden and, therefore, cannot be younger than the Coniacian. The Atane beds are reported to be separated from adjoining formations by unconformities.

10. The Kome beds contain a flora that was at first referred to the Barremian and Aptian stages (Heer, 1883), but later because of the presence of a dicotyledon was referred to the Albian (Berry, 1911; Ravn, 1918). Brown (1946, pp. 246, 247) notes that the Kome beds contain many species in common with the Kootenai formation of Montana and with the Lower Blairmore formation of Canada and that the Lower Blairmore has furnished a single dicotyledon. The Lower Blairmore formation is correlated with the Aptian stage on the basis of its flora (Berry, 1929; Bell, 1944). This correlation seems reasonable, because the Lower Blairmore passes northward in Alberta and British Columbia into interbedded nonmarine and marine beds that underlie marine beds containing Lemuroceras and Beudanticeras (McLearn, 1945), both definite Albian genera. The range of Lemuroceras is not known, but in Madagascar it occurs with many other ammonites that mark the basal middle Albian zone of Douvilleiceras mammillatum (Collignon, 1949, pp. 103-110). This dating of Lemuroceras shows that the Lower Blairmore might include beds of early Albian age but certainly nothing younger. By comparison the Kome beds of West Greenland probably represent the Aptian and part of the Albian.

11. Some shales exposed on the coast of the southern part of the Svartenhuk Peninsula have furnished ammonites related to Scaphites ventricosus Meek and Hayden (Rosenkrantz et al., 1942, p. 38). Such Scaphites in the western interior of the United States are not known in beds older than the Coniacian. Associated with them in West Greenland are specimens that "seem to belong to the genus Borissjakoceras" (Rosenkrantz et al., 1942, p. 39). This genus in the western interior is known only in beds of Cenomanian and Turonian age not younger than the lower part of the Carlile shale. Possibly the ammonite from West Greenland really belongs to the genus Binneyites, which is similar to Borissjakoceras.

12. In southeastern Alaska (Fig. 2) the presence of beds of Berriasian age is indicated by one large collection of Aucella subokensis Pavlow (Mes. loc. 10147) from Slocum Arm on the west side of Chichagof Island. The presence of beds of Valanginian age is indicated by typical specimens of Aucella crassicollis Keyserling from Kruzof Island (Mes. loc. 17845), Admiralty Island (Mes. locs. 8850, 8855), and Etolin Island (Mes. locs. 8840, 11077). On

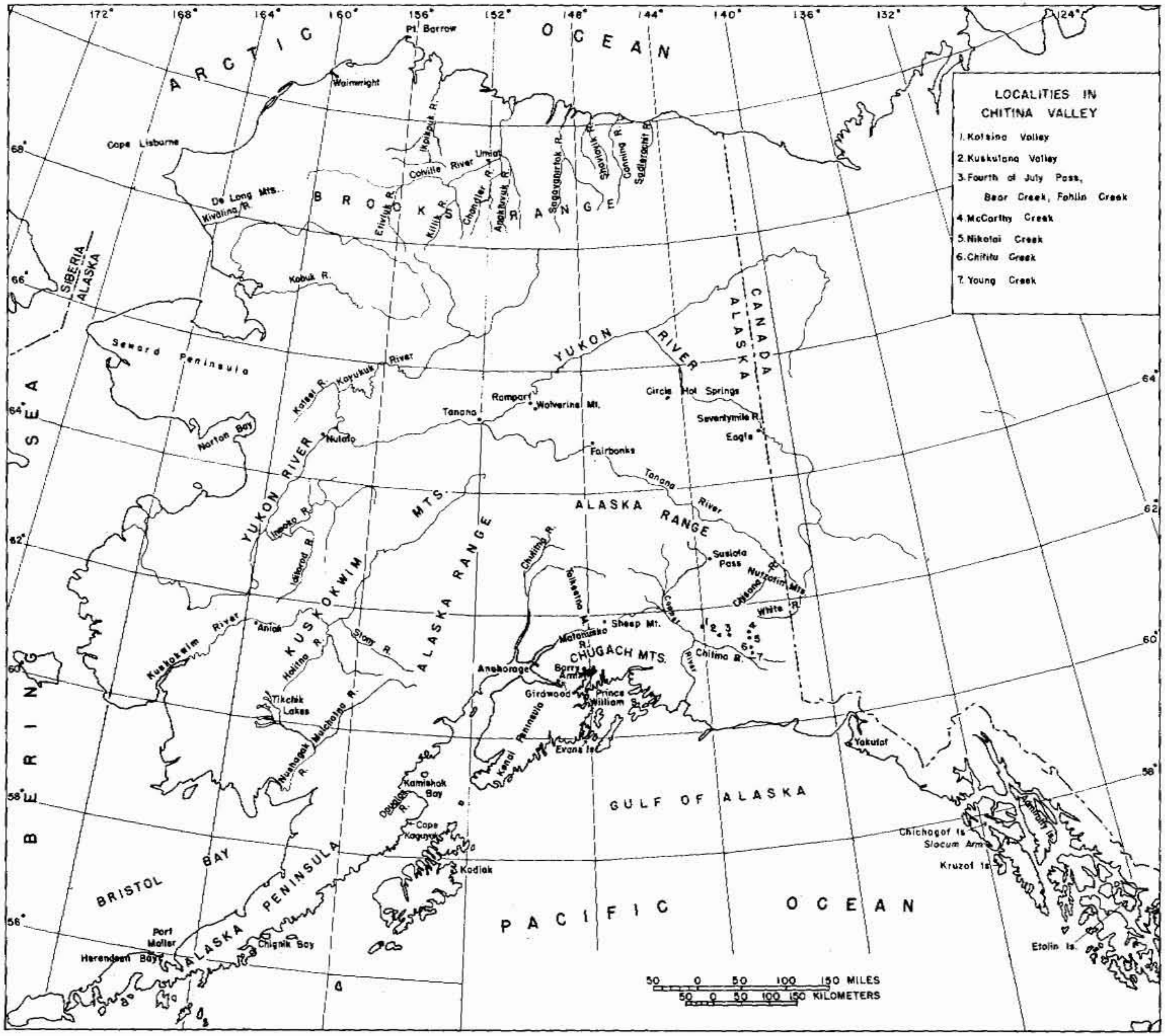

FIGURE 2. - INDEX MAP OF ALASKA

Admiralty Island at Pybus Bay this species occurs in 300 to 400 feet of dark gray shale that is underlain by conglomerate and pebbly shale at a point between two arms of the bay (Martin, 1926, pp. 377-378). This pebbly shale has furnished many specimens of Aucella (Mes. locs. 3309, 8851, 10095, and 10169) that belong to A. piochii Gabb or to similar species characterized by an elongate form and a narrow umbo. Such aucellas in California are common in the Knoxville formation of latest Jurassic age and rare in the overlying Paskenta group of Early Cretaceous age (Anderson, 1945, pp. 964, 965). In the Arctic region of Europe and Asia they characterize beds of Portlandian age. The aucellas that have been obtained from Kupreanof Island and Gravina Island (Martin, 1926, pp. 253, 379-382) are not of Early Cretaceous age, as they belong to Aucella rugosa (Fischer) and Aucella cf. A. mosquensis (von Buch), which in Russia range through the upper Kimmeridgian into the basal Portlandian not higher than the zone of Zaraiskites albani (Arkell, 1946, pp. 24-26; Spath, 1936, p. 167; Pavlow, 1907, table opposite page 84).

13. The Mesozoic is represented along the mountainous Pacific Coast of Alaska from Yakutat to Kodiak Island by a thick sequence of slate, graywacke, arkosic sandstone, minor amounts of conglomerate and grit, and large masses of dark extrusive and intrusive rock. These rocks have been included in the Yakutat group in the Yakutat Bay area, in the Valdez and Orca groups in the Chugach Mountains north of Prince William Sound, and in the Sunrise group on the Kenai Peninsula (Martin, 1926, pp. 480-487; Moffit, 1938, pp. 89-92). Throughout this distance of nearly 700 miles reliable fossil evidence concerning the age of these Mesozoic beds has been found in only three small areas, one on Barry Arm in the Port Wells district north of Prince William Sound, one near Girdwood on the north side of Turnagain Arm southeast of Anchorage, and the other on a small island near Kodiak. Curiously, these three areas contain identical species of Inoceramus characterized by bearing radial marking. The collections from Girdwood (Mes. locs. 7238, 7378, 15965-15968) and Barry Arm (Mes. loc. 8601) contain species of Inoceramus that can be matched with western interior species that occur in the zone of Scaphites binneyi Reeside (Cobban, 1951, p. 2197). One of these species obtained near Kodiak was described by Ulrich (1904, pp. 134-136, pl. 12, figs. 1, 2, pl. 13, fig. 1) as Inoceramya concentrica Ulrich. On the same slab as the type of Inoceramya concentrica Ulrich is a fragment of another Inoceramus with strong radial ribbing identical with one of the species from Turnagain Arm. Both of these species are associated in the western interior in the Scaphites binneyi zone at Mes. loc. 21097 in the lower part of the Cody shale, Wyoming, and at Mesozoic locality 11951 in the Mancos shale near Price, Utah. The corresponding position in Europe would be either upper Coniacian or lower Santonian.

The Late Cretaceous age shown by these species of Inoceramus at the three localities is supported by the occurrence of a comatulid crinoid on the west side of Evans Island in the western part of Prince William Sound near the Kenai Peninsula (Johnson, 1916, p. 198). This crinoid was reported by A. H. Clark to belong to a group not known before the Jurassic and to be closely related to a crinoid now living in Alaskan waters.

The close dating of the thick sequence of slate and graywacke at only three places is not evidence that the entire sequence is so narrowly dated throughout its area of distribution. It seems probable that it represents much more than the small interval of time indicated by the Inoceramus. For example, a collection containing earliest Cretaceous Aucellas was made by R. P. Sharp in graywacke in the St. Elias Mountains, Canada, on a ridge about ten miles due east of the summit of Mt. Logan and four miles southeast of McArthur Peak. According to Don J. Miller [4], "These fossils apparently are from a graywacke sequence which is widespread in the Alaskan part of the St. Elias Mountains and which forms a considerable part of the Chugach Mountains farther west."

4/ Personal communication of January 9, 1951.

The aucellas in question are poorly preserved, but comparisons may be made with Aucella okensis Pavlow, A. subokensis Pavlow, and A. volgensis Lahusen. If correctly identified, these would represent the Berriasian stage of the very base of the Lower Cretaceous. Regardless of specific identity, they are large, stout Aucellas such as characterize the earliest Cretaceous of the Boreal region and the Pacific Coast of North America from California northward.

Considering these age determinations and the age and distribution of Cretaceous deposits in other parts of Alaska, it seems probable that the slate and graywacke sequence includes equivalents of all the Cretaceous to the north in the Copper River region, in the Cook Inlet region, and in southwestern Alaska, and was originally deposited as sediments in the same seas that covered those regions. This statement does not preclude the possibility that Jurassic or older rocks may somewhere be represented in the slate and graywacke sequence.

14. The Kennicott formation of the Chitina Valley, as defined by Martin (1926, p. 349), includes Lower Cretaceous strata at Fourth of July Pass, Kuskulana Pass, Bear Creek and Fohlin Creek east of Kuskulana Pass, and the headwaters of McCarthy Creek. Generalized sections of the Lower Cretaceous deposits have been published by Moffit (1938, pp. 71-78), who notes that the basal beds are generally conglomerate or grit of irregular thickness. These are overlain by 300 to 500 feet or more of sandstone and sandy shale that contain calcareous concretions. Above follows black shale that locally is at least 3000 feet thick and includes some sandstone and conglomerate. At the top is 2500 feet or more of conglomerate, sandstone, and sandy shale that have not furnished fossils and may be younger than the Early Cretaceous. Studies of the mollusks of the Kennicott formation show that at least three assemblages are present. Two of these assemblages include species identical with species in the upper part of the Horsetown formation of California (Anderson, 1938). The other assemblage is possibly present in California but is present for certain on the Queen Charlotte Islands and has been described in various papers by Whiteaves (1876, 1879, 1884, 1893, 1900, 1903).

The molluscan assemblage that is best represented in the Geological Survey collections from the Kennicott formation is probably the oldest. It is characterized by an abundance of the pelecypod Aucellina and is the only assemblage that contains this genus. It includes such ammonites as Lemuroceras deansii (Whiteaves), L. cf. L. besairiei (Collignon), L. cf. L. indicum (Spath), L. lecontei (Anderson), L. cf. L. taffi (Anderson), Pseudosonneratia sp., Sonneratia ? rogersi Hall and Ambrose, Puzosia subquadrata Anderson, and Lytoceras (Kossmatella) aurarium Anderson. Identical or similar species are present in the upper part of the Horsetown formation in beds that Anderson (1938, table 2, p. 68) refers to his LeConte and Perrin zones. This assemblage is well represented in collections from U.S.G.S. Mes. locs. 2147, 2191, 2201, 8872, 8873, 8876, 8877, 8878, 9478, 9489, 9971, 9972, 9978, 14485, 14487, and 14848 in the Kennicott formation.

A second assemblage considered slightly younger than the preceding is represented by a large collection from U.S.G.S. Mes. loc. 9492. It contains such ammonites as Arcthoplites cf. A. jachromensis (Nikitin), Cleoniceras, Beudanticeras haydeni (Gabb), B. breweri (Gabb), Lytoceras (Tetragonites) timotheanum (Mayor), L. (Gaudryceras) sacya Forbes and the pelecypods Inoceramus concentricus Parkinson and I. cf. I. anglicus Woods. Many of these species are identical with species occurring near the top of the Horsetown formation in beds that Anderson (1938, table 2, p. 68) refers to his Neptune zone.

A third assemblage, represented at Mes. Locs. 9481, 9485-9487, 14511, and 14514, contains the same species of Beudanticeras and Lytoceras as the second assemblage, but in addition contains the ammonites Holcodiscoides cumshewaensis (Whiteaves) (1884, p. 208, pl. 24, fig. 1; 1900, p. 278) and H. aff. H. papillatus (Stoliczka) (1865, p. 159, pl. 77, figs. 7, 8). The common Inoceramus is a coarsely plicate form identical with I. concentricus var. subsulcatus Wiltshire. This assemblage is characterized by the presence of Holcodiscoides, which genus was based on a species from the Cenomanian of India (Spath, 1922, p. 124; Stoliczka, 1865, p. 157, pl. 77, figs. 3, 3a). The genus is represented in the Cretaceous of California by a species described by Anderson (1902, p. 101, pl. 5, figs. 126, 127, pl. 10, fig. 197).

An Albian age for all three of these assemblages is proven by the occurrence of Pseudosonneratia, Sonneratia ?, Lemuroceras, Cleoniceras, Arcthoplites, Beudanticeras, and the species of Inoceramus listed.

The assemblage containing Pseudosonneratia, Sonneratia ?, rogersi Hall and Ambrose, and abundant Lemuroceras represents either the upper part of the lower Albian or the lower part of the middle Albian on the basis of the known ranges of these genera. This age is confirmed by the identity of some species with species in the LeConte and Perrin zones of Anderson in the upper part of the Horsetown formation in California. This part can be dated approximately by the presence of Douvilleiceras, which in Europe ranges through the zones of Leymeriella tardefurcata and Douvilleiceras mammillatum. A suggestion that the assemblage in question represents the lower rather than the middle Albian is furnished by Sonneratia ? rogersi, which is similar to the early Albian Uhligella balmensis Jacob (1907, p. 33, pl. 4, figs. 6-9). Also, the identity of the common species in the Kennicott formation with those in the Haida formation on the Queen Charlotte Islands and the presence of Leymeriella haidaquensis (Whiteaves) (1893, p. 444, pl. 7, figs. 2a, b) in those islands suggests that the Leymeriella tardefurcata zone is represented in both areas.

The assemblage in the Kennicott formation that contains Arcthoplites, Cleoniceras, abundant Beudanticeras and Lytoceras, and the pelecypod Inoceramus concentricus Parkinson is probably not older than the Douvilleiceras mammillatum zone, because Beudanticeras is uncommon and I. concentricus is unknown below that zone. Arcthoplites in Greenland ranges from the upper part of the lower Albian into the middle Albian (Spath, 1946, p. 9). In Russia it is recorded with Hoplites dentalus Sowerby of the middle Albian (Bogoslowsky, 1902, p. 128, 153, pl. 7, figs. 3a-c, pl. 8, figs. 1a, b, pl. 6, fig. 4). Cleoniceras is not known above the zone of

Douvilleiceras mammillatum. The identity of some of the species of Beudanticeras and Lytoceras with species from the highest part of the Horsetown formation in Anderson's Neptune and Packard zones (1938, table 2, pp. 68, 69) suggests a middle Albian age assignment because that part of the Horsetown has furnished the ammonite Oxytropidoceras (Anderson, 1938, p. 198, pl. 50, fig. 1). This genus is typical of the middle Albian, although it has been recorded from the upper part of the lower Albian (Spath, 1942, p. 707). It is interesting that the highest part of the Horsetown formation has, also, furnished two species of Gastroplites (Anderson, 1938, p. 196), which genus is known elsewhere in Alaska, the western interior of Canada, Greenland, and England. It has been accurately dated only in England, where it occurs at the top of the middle Albian (Spath, 1937, pp. 257-260).

The third assemblage in the Kennicott formation is undoubtedly only slightly younger than the assemblage with Arcthoplites as it contains species of Beudanticeras and Lytoceras in common, although the presence of Holcodiscoides might indicate an age as late as Cenomanian and the coarsely plicate Inoceramus concentricus var. subsulcatus Wiltshire might be taken as evidence of late Albian age. However, Beudanticeras is not known to range above the basal part of the Pervinquieria inflata zone of the late Albian in Europe (Spath, 1942, p. 691), and this well-known genus affords much more positive evidence of age than the poorly known genus Holcodiscoides. Also, the coarsely plicate variety of Inoceramus concentricus is reported to be characteristic of the zone of Pervinquieria inflata.

In summation, the Kennicott formation contains three molluskan assemblages that can be correlated with certainty with beds of the Albian stage of the latest Early Cretaceous in California, in the Queen Charlotte Islands, and in Europe. The evidence is so overwhelmingly in favor of such a correlation that students of mollusks would accept the age determination without qualifications.

In contrast, the students of plant fossils have maintained that the age of the Kennicott formation is either Late Jurassic or earliest Cretaceous. Knowlton (Moffitt, 1918, pp. 42-44; Martin, 1926, pp. 344-346) was very positive about this determination and his conclusions have been confirmed recently by Roland W. Brown 5/

5/ Personal communication.

who notes the similarities of the plants with those in the Knoxville formation and Paskenta formation in California. However, it should be noted that the plants in the Kennicott formation are associated with lower and middle Albian ammonites of which many species are identical with species in the upper part of the Horsetown formation of California. Unfortunately the flora in the Horsetown formation has not been described so that the composition of its flora is not known. Bearing on this problem is the identity of some of the plant species in the Kennicott formation with species in the Corwin formation in the Cape Lisburne area of northwestern Alaska (Martin, 1926, pp. 456-466), which Knowlton (1914, p. 43) likewise maintained to be of Jurassic age, but which has been traced northeastward into the upper part of the Torok formation of Albian age and into the Nanushuk group which is partly of Albian age.

15. The Matanuska formation consists of a basal sandstone member as much as several hundred feet thick, an overlying shale member several thousand feet thick, and an upper member of sandstone, siltstone, and shale about a thousand feet thick. Both the basal sandstone and the sandstones near the top of the formation are conglomeratic locally and vary somewhat laterally in thickness and lithologic characteristics. The formation rests unconformably on rocks ranging in age from Early Jurassic to Early Cretaceous. In most places it is overlain concordantly by early Tertiary rocks which suggests that the contact does not represent more than a disconformity. In the mountains west of Kings River, however, the Matanuska formation is reported to be overlain with angular unconformity by early Tertiary rocks (Martin and Katz, 1912, pp. 15, 23, 34-39; Martin, 1926, pp. 317-321; Capps, 1927, pp. 35-40; personal communication from Arthur Grantz).

The fossils obtained from the Matanuska formation indicate that the formation represents only the upper part of the Upper Cretaceous. The basal sandstone and the immediately overlying several hundred feet of shale are probably of Coniacian age as indicated by their stratigraphic position below shales containing Inoceramus undulatoplicatus Roemer, by the presence of Parapuzosia and Prohauericeras, and by species of Inoceramus that are probably identical with I. uwajimensis Yehara and I. naumanni Yokoyama from the Paleourakawan stage of Japan (Nagao and Matumoto, 1939, pp. 286-291, pl. 34, figs. 1, 3, 4, 6, pl. 35, figs. 1-3; 1940, pp. 31-36, pl. 14, figs. 1-10, pl. 15, figs. 1-2). The ammonite Prohauericeras occurs in both the Turonian and Coniacian of Europe but is more common in the Coniacian. The species of Inoceramus in Japan are associated with some ammonites that are not known above the Coniacian, or are restricted to it, and they overlie beds (Neogyliakian) that contain Turonian ammonites (Matumoto, 1942, pp. 147-149). An age younger than Turonian for the basal beds of the Matanuska formation is indicated also by the absence of certain species of Inoceramus that characterize beds of Cenomanian and Turonian age in the western interior of Canada, in the Kuskokwim region of western Alaska, and in northern Alaska north of the Brooks Range.

Overlying the lowermost several hundred feet of shale is a somewhat greater thickness of shale containing calcareous concretions and lenses and characterized by many specimens of Inoceramus undulatoplicatus Roemer. Fragmentary pachydiscid ammonites were found at two localities. The age of the shale containing I. undulatoplicatus Roemer, judging by occurrences of this species in Europe (Woods, 1911, p. 6; Heintz, 1928, p. 76, pl. 3), Texas (Adkins, 1933, pp. 452, 453), and the western interior of the United States (Cobban and Reeside, 1952, p. 1019), is either Coniacian or Santonian and probably mostly early Santonian.

In Japan I. undulatoplicatus and its varieties is apparently included under I. japonicus Nagao and Matumoto and perhaps also under I. schmidti Michael (Nagao and Matumoto, 1940, pp. 24-28, 41-44) which occur in the Japanese Neourakawan, Infra-hetonian and Paleohetonian stages. These have been correlated with the European Santonian, Campanian, and Maestrichtian stages respectively (Matumoto, 1943, p. 229). Judging from the lists of fossils reported from the Japanese stages just mentioned (Matumoto, 1943, pp. 127-134, 149-151), there is no positive evidence for placing these stages higher than the Santonian. In regard to correlation Matumoto (1943, p. 229, 230) notes that "We likewise meet with difficulties when we attempt to correlate in detail the finer divisions of the Urakawan + Hetonian with those of the Senonian (s.l.), except, however, the Paleourakawan and Coniacian which, in turn, approximately correspond with each other."

Correlation of the Paleourakawan with the Coniacian is based on such ammonites as Nowakites, "Barroisiceras," and perhaps Parapuzosia indopacifica Kossmat. It is evident, however, that the Japanese paleontologists are rather uncertain about correlations of the higher Cretaceous strata. One fact suggesting that some of the Japanese stages for the late Cretaceous may not represent as much time as European stages is the distribution of many of their ammonite species through two or three Japanese stages (Matumoto, 1943, pp. 110-134). Such long durations for ammonite species does not agree with the known ranges of most ammonite species in Europe and North America.

Bearing on the age of the beds in the Matanuska formation that contain Inoceramus undulatoplicatus Roemer is the occurrence of this species on Vancouver Island (Whiteaves, 1879, p. 168, pl. 20, figs. 2, 2a). It is presumably the same species referred to as I. cf. I. schmidti Michael by Ushur (1952, p. 10, 11, 22, 25, 37, 38, 41) in his studies of the ammonite faunas of the Upper Cretaceous of Vancouver Island. He reports this Inoceramus from the Haslam, Qualicum, and Trent River formations which he refers to the Campanian stage, although admitting that the ammonite evidence is not conclusive. His age determination was probably influenced partly by various Japanese publications dealing with Upper Cretaceous ammonites and partly by the fact that the Lambert formation, which occurs only about a thousand feet above the Trent formation, contains an ammonite assemblage that he regards confidently as of Maestrichtian age.

In the Matanuska formation some hundreds of feet of shale lying above beds containing I. undulatoplicatus Roemer are poorly exposed and have not furnished fossil material of known age significance. The next higher faunal assemblage was obtained from the lower part of the upper third of the shale member. It is characterized by Pachydiscus suciaensis (Meek), Nostoceras hornbyense (Whiteaves), Desmophyllites ("Schluteria") selwyniana (Whiteaves), Neophylloceras ramosum (Meek), Gaudryceras denmanense Whiteaves, Diplomoceras notabile Whiteaves, Anisoceras cooperi Gabb, Polyptychoceras ? obstrictum (Jimbo), and Inoceramus subundatus Meek. These species are found elsewhere in the Northumberland and Lambert formations on Vancouver Island which Ushur (1952, pp. 19, 27, 34, 40) correlates with the lower part of the European Maestrichtian stage. His correlation appears to be based mainly on the smoothness of the adult shells of the pachydiscid ammonites, on the abundance of uncoiled ammonites, and on comparisons with the described ammonites from the Navarro group of Texas and from the late Cretaceous beds of various areas bordering the Pacific Ocean.

The Northumberland and Lambert formations can just as reasonably be correlated with the Campanian as with the Maestrichtian stage on the basis of the ammonite genera present. An age determination based on smoothness of adult pachydiscid ammonites seems risky considering how little is actually known about the family. Comparisons with the ammonites of the Navarro group merely reflects the fact that many of the ammonites of the Navarro are described whereas most of the ammonites of the Taylor group and Austin chalk are undescribed. Comparisons with the latest Cretaceous ammonite assemblages in southernmost South America, Antarctica, and India are of little value as far as exact correlations with the Campanian or Maestrichtian stages are concerned, because the latest Cretaceous in those areas has not been studied in any detail. The ammonite collections have been made mainly with respect to gross lithologic units. In fact the reported occurrence of certain species of ammonites from several different formations, some of which are separated by unconformities, suggests that some of the collections have been mixed. In Japan where considerable detailed stratigraphic work has been done, the Japanese paleontologists admit their inability to make exact correlations with the European stages above the Coniacian (Matumoto, 1943, pp. 229-230). It seems evident that much more paleontological and stratigraphical work is needed dealing with the Cretaceous rocks exposed in areas bordering the Pacific Ocean before many positive correlations can be made with the European stages.

The highest fossils obtained from the Matanuska formation are from the upper third of the shale member. They include Pachydiscus, a large, round, flat weakly ornamented Inoceramus similar to I. sagensis Owen, and an elongate, fairly strongly ribbed Inoceramus similar to I. simpsoni Meek or to I. barabini Meek (not Morton). These species of Inoceramus in the western interior of the United States occur in the upper part of the Pierre shale in beds of late Campanian to early Maestrichtian age.

In summation, the Matanuska formation is equivalent to at least the Coniacian to Campanian stages of Europe. The highest beds may be Maestrichtian. There is no evidence that the basal beds are older than Coniacian.

The Matanuska formation has been traced from the head of the Matanuska Valley eastward nearly 40 miles to near Tazlina Lake and probably extends much farther eastward. It has been identified faunally on the north side of the Chitina Valley along Chititu and Young Creeks where it is about 8000 feet thick and consists of three members similar to those in the Matanuska Valley area (Moffit and Capps, 1911, pp. 31-38; Martin, 1926, pp. 360-369). The exposures along these creeks have not been collected stratigraphically but some fossils obtained from the lower 4500 to 5000 feet of the formation have been identified by Stanton (Martin, 1926, p. 365) as definitely Late Cretaceous. This age determination is now confirmed by the presence of the ammonites Parapuzosia (Mes. locs. 4811, 8858, 8862, 8866, 8869) and Pachydiscus ? (Mes. loc. 8858), and by a fragment of a large Inoceramus (Mes. loc. 8860) showing the peculiar digitate ribbing of I. undulatoplicatus Roemer. These fossils indicate a Coniacian to Santonian age. The reported occurrence of ammonite shells as much as 18 inches in diameter from the upper slopes of the mountains bordering Chititu and Young Creeks (Moffit and Capp, 1911, p. 34) suggest the presence of large pachydiscid ammonites similar to those in the upper part of the Matanuska formation in the eastern part of the Talkeetna Mountains.

Elsewhere in the Chitina Valley the Matanuska formation is probably represented by sandstone and conglomerate that rest unconformably on Triassic rocks at the head of Nikolai Creek (Moffit and Capps, 1911, pp. 31-40), at Dan Creek (Martin, 1926, p. 358), and in the Kotsina and Kushulana Valleys (Moffit and Mertie, 1923, pp. 20, 44-51). The fossil evidence is rather meager and consists of an Inoceramus comparable to I. uwajimensis Yehara at Mes. locs. 2198, 6302, 6309, 8924, and 8936. The occurrence of such an Inoceramus indicates that the sandstone and conglomerate in question are probably equivalent to the basal few hundred feet of the Matanuska formation at the head of the Matanuska Valley and in the southeastern part of the Copper River Basin. If these correlations are correct the massive 1,000 to 2,500 feet of the Kotsina conglomerate in the area of Kotsina River and Strelna Creek (Moffit, 1938, p. 67) is equivalent to the basal part of the Matanuska formation rather than to the lower part of the Kennicott formation.

16. The Nelchina limestone, according to information furnished by Arthur Grantz of the Geological Survey, is sandy, ranges from 30 to 170 feet or more in thickness, rests locally with conformity on 100 to 200 feet of conglomerate and sandstone and is overlain by about 100 feet of soft shale and sandstone. The underlying conglomerate and sandstone contains innumerable well-preserved specimens of Aucella crassa Keyserling and Aucella crassicollis Keyserling. The latter species is characteristic of the Valanginian in the Boreal region and is reported to reach its maximum abundance during the middle Valanginian. An age not younger than Valanginian for the limestone is indicated by the presence of the deeply grooved belemnite genus Belemnopsis on the surface of the limestone and in an immediately overlying sandstone.

17. Ammonites of Late Cretaceous age, probably Campanian, have been found at Cape Kaguyak on the Shelikof Strait in the upper part of a sequence consisting of about 400 feet of black siltstone and thin beds of limestone overlying the Naknek formation (Hazzard, 1950, p. 227). The ammonites include Pachydiscus cf. P. ootacodensis Stoliczka, P. cf. P. suciaensis (Meek), Phylloceras ramosum Meek, Gaudryceras cf. G. denmanense Whiteaves and Diplomoceras notabile Whiteaves. With these is one specimen of Inoceramus that is probably an immature form of I. subundatus Meek. These ammonites and the Inoceramus are identical with species in the upper third of the Matanuska formation of the Cook Inlet district, Alaska and with species from Vancouver Island and nearby islands described by Whiteaves (1879, 1903), Meek (1876), and Usher (1952). In the Matanuska formation these species occur many hundreds of feet above beds containing Inoceramus undulatoplicatus Roemer, which occurs nearly world-wide at the base of the Santonian. Therefore, stratigraphic position alone shows that the faunule is younger than lower Santonian. In Vancouver Island these species occur in the Lambert formation and the lower part of the Northumberland formation and are dated by Usher (1952, pp. 19, 27, 34, 39) as Maestrichtian. A similar faunule from Lower California was described by Anderson and Hanna (1935) and was reported by them (1935, pp. 16, 17) to be widespread in California in the upper part of the Panoche formation, which they correlated with the Campanian.

18. Ammonites of Late Cretaceous age have been obtained southwest of Kamishak Bay from greenish gray silty sandstones, at least 2000 feet thick, that rest on the Upper Jurassic Naknek formation (Hazzard et al., 1950, p. 226). From a sea cliff near the

mouth of Douglas River was obtained Collignoniceras (Prionotropis), which, if correctly identified, is evidence of a Turonian age. Other collections made about seven miles southeast of the mouth of the Kamishak River include ammonites that indicate a Late Cretaceous age younger than the Cenomanian. The age of the lowest part of the sandstone sequence is not known.

19. The Chignik formation near Chignik Bay and Herendeen Bay consists of 600 to 800 feet of sandstone, shale, conglomerate, and coal that were deposited during only a small part of Late Cretaceous time. Determination of its age is based mainly on the presence throughout of the coarsely plicate Inoceramus undulatoplicatus Roemer, a species which occurs worldwide near the Coniacian and Santonian boundary. Of possible age significance is the presence near the top of the Chignik formation of a large specimen of Pachydiscus (Mes. loc. 5580) that is identical with P. multisulcatus (Whiteaves) (1903, p. 349, pl. 50; Ushur, 1952, p. 81, pl. 16, figs. 1-4, pl. 31, fig. 8) from the Nanaimo group of Vancouver Island. Its occurrence on Vancouver Island is in the Qualicum formation which Ushur (1952, p. 7, 22, 38) correlates with the lower part of the Campanian on the basis of stratigraphic position. The presence in the Qualicum formation of strongly plicate Inoceramus similar to, or identical with I. undulatoplicatus Roemer suggests, however, that the formation may not be younger than Santonian.

20. The Herendeen limestone of Herendeen Bay and Port Moller is correlated with the lower and middle Valanginian because it contains numerous well-preserved specimens of Aucella crassicollis Keyserling. There is no faunal evidence that it includes rocks of Berriasian age. It rests concordantly on the Staniukovich shale, which contains aucellas with narrow, elongate umbones comparable with A. piochii Gabb. This type of Aucella is characteristic of Portlandian beds in California and northern Eurasia and has not been found anywhere in Alaska associated with aucellas of Early Cretaceous age. Mesozoic collection 5572 (Martin, 1926, p. 292), which Atwood (1911, p. 40) could not locate for certain stratigraphically because of a thick snow cover, contains the same type of Aucella as found elsewhere in the Staniukovich shale. In addition it contains a few small, plump aucellas that Stanton (in Martin, 1926, p. 295) compared with A. crassicollis Keyserling but which can be matched better in the Russian Portlandian by such a species as A. subinflata Pavlow (1907, p. 67, pl. 6, figs. 1-4) or in the Berriasian by A. inflata Toula (Pavlow, 1907, p. 68, pl. 6, figs. 5a-c). At least, these aucellas lack the swollen umbones and prominent constrictions that characterize A. crassicollis Keyserling. Another collection (Mes. loc. 5587) that Atwood considered to belong in the Herendeen limestone contains ammonites and Inoceramus of Late Cretaceous age and probably was obtained from the basal part of the Chignik formation.

21. The upper part of the Lower Cretaceous is probably represented in the Nutzotin Mountains by 300 to 1000 feet, or more, of conglomerate, sandstone, shale, tuff, lava flows, and locally lignitic coal (Capps, 1916, pp. 53-57; Moffit, 1943, pp. 127-129) that are less indurated and less folded than the underlying basal Cretaceous (Valanginian) or Jurassic rocks. Plant fossils from these higher beds were once identified by F. H. Knowlton as probably Tertiary (Capps, 1916, p. 57) and later by Roland Brown (Moffit, 1943, p. 128) as Upper Cretaceous. However, one collection (Plant loc. 8908) according to determinations by Brown contains Sequoia reichenbachi (Geinitz) Heer, which occurs in beds of Albian age in the Yukon region (see Annotation 31), and Cladophlebis septentrionalis Hollick, which occurs in beds of Coniacian to Santonian age on the Alaska Peninsula (see Annotation 19). Another collection (Plant loc. 6806) according to Brown contains Gleichenia nordenskioldi Heer, a species originally found in the Kome beds of west Greenland. The Kome beds contain many species in common with the Kootenai formation of Montana and the Lower Blairmore formation of Canada and are probably mostly of Aptian age (see Annotation 10). Most of the evidence, therefore, points to an Early Cretaceous age that is approximately the same as that of the Cantwell formation of the Alaskan Range and the Shaktolik group of the lower Yukon region.

22. A thick sequence of black shale and graywacke exposed near the Chisana and White Rivers in the Nutzotin Mountains has furnished a few specimens of Aucella crassicollis Keyserling and A. sublaevis Keyserling (Mes. locs. 8807, 8808, 8810, 18339), which species occur in the Valanginian of the Boreal region. The aucellas from Mes. locs. 8811 and 18349 resemble A. piochii Gabb and are probably of late Jurassic age younger than the Naknek formation.

23. The Cantwell formation consists of several thousand feet of continental deposits and some interbedded lavas and graywacke. It is well-indurated but is metamorphosed only near fault zones. It rests with probably unconformity on slates and graywackes that have furnished fossils of Late Jurassic and earliest Cretaceous age (see Annotation 24). It is overlain by several thousand feet of continental Eocene strata that are much softer and less faulted and folded (Capps, 1940, pp. 112-118) and have furnished many plant fossils.

The age of the Cantwell formation for many years was considered as probably Eocene on the basis of a few fragmentary plants. In 1936, however, Ralph W. Chaney accompanied S. R. Capps to a fossil locality (Plant loc. 7278) and collected eight species that are characteristic of the Cretaceous flora of Alaska (Capps, 1940, p. 118; R. W. Chaney, memorandum of Jan. 30, 1937). The species identified by Chaney are as follows:

1. Podozamites lanceolatus Braun

2. Cephalotaxopsis microphylla laxa Hollick

3. Sequoia obovata Knowlton

4. Populites mirabilis Hollick

5. Castaliites ordinarius Hollick

6. Credneria inordinata Hollick

7. Pseudoprotophyllum dentatum Hollick

8. Zizyphus electilis Hollick

Among the above species, Sequoia obovata and Zizyphus electilis occur elsewhere in Alaska in the Chignik formation of the Alaska Peninsula. This formation on the basis of its mollusks is of late Coniacian to early Santonian age (see Annotation 19). The other species listed are common in the lower Yukon region in either the Melozi formation, or the Kaltag formation, or in both. Podozamites lanceolatus occurs also in the Nulato formation, which lies between the Melozi and Kaltag formations and is dated on the basis of the ammonite Gastroplites as mainly upper Albian.

Assignment of the Cantwell formation to the Albian agrees with the field observations that the formation was subjected to considerable orogenic movements before the overlying continental beds of Eocene age were deposited.

24. Part of the thick sequence of slate and graywacke underlying the Cantwell formation has been assigned previously to a Late Cretaceous age on the basis of two crushed fragments of Inoceramus (Mes. locs. 10124, 10125) obtained on Long Creek in the Yentna district. These fragments represent a large, compressed species of Inoceramus, which kind occurs commonly in the Upper Cretaceous but is also known in the Lower Cretaceous and in the Jurassic. Such fragments generally have little significance for close age determinations.

The Valanginian is represented at least locally in the slate and graywacke sequence cropping out on the flank of the Alaska Range. One fossil collection (Mes. loc. 15414) made by Capps (1933, pp. 260-264; 1940, p. 111) from the West Fork of the Chulitna River contains some crushed aucellas that probably belong to Aucella crassicollis Keyserling. At least one specimen has the umbonal swelling and pronounced constriction that characterizes that species and several other specimens have the irregular, thick concentric ribs that are common in aucellas of Valanginian age.

Beds of supposed Valanginian age in the eastern part of the Alaska Range in the Suslota Pass district (Moffitt, 1933, p. 154) are in part at least incorrectly identified. The aucellas from Mesozoic locality 16085 belong to A. rugosa (Fischer) which ranges from the middle Kimmeridgian to the basal Portlandian. The Aucella from Mesozoic locality 16259 is an indeterminable right valve that might be either Late Jurassic or Early Cretaceous in age.

25. Several thousand feet of continental rocks exposed on the banks of the Yukon River near Seventymile River have furnished plant fossils that are reported to be partly Upper Cretaceous and partly Eocene (Mertie, 1930, pp. 141-146; Hollick, 1930, pp. 18, 19, 34; 1936, p. 31). The Cretaceous plants indicate a correlation with the Kaltag and Melozi formations of the lower Yukon region, which are of Albian age, although the Kaltag possibly extends into the Cenomanian.

26. Only the Berriasian and Valanginian stages of the Lower Cretaceous have been identified in collections from the Kandik formation in the Eagle district (Mertie, 1930, pp. 136-141). The Berriasian is represented by Aucella okensis Pavlow at Mes. loc. 2674. The Valanginian is represented by Aucella sublaevis Keyserling at Mes. locs. 3785 and 13429.

27. The presence of middle Albian in the Wolverine Mountain area in the Hot Springs - Rampart districts is proven by the presence of many specimens of the ammonites Cleoniceras from Mes. locs. 4278, 4279, and 8900 and Gastroplites at Mes. locs. 4278 and 4280. The species at loc. 4280 is similar to G. spiekeri McLearn. Previous reference to the Upper Cretaceous of the beds containing these fossils was based mainly on erroneous identification of the mollusks and on the insistence of botanists that the plants were of early Late Cretaceous age (Martin, 1926, pp. 392-394; Mertie, 1937, pp. 166-170).

28. Earliest Cretaceous not younger than Valanginian is possibly represented in the Hot Springs - Rampart districts, as indicated by some small aucellas (Mes. locs. 11390, 11391 and 15981) similar to A. sublaevis Keyserling. The preservation of the aucellas does not permit a positive identification but their plump shape is suggestive of an early Cretaceous rather than a Jurassic age.

29. A thick sequence of sandstone, shale, conglomerate and limestone exposed in the lower part of the Koyukuk Valley below the Kateel River resembles the Shaktolik group of the lower Yukon and is identified with that group on the basis of a few plants (Martin, 1926, pp. 444-446; Martin in Hollick, 1930, pp. 32, 33). A similar appearing sequence of rocks in the upper part of the

Koyukuk Valley has been called the Bergman group (Schrader, 1904, pp. 77, 78; Martin, 1926, pp. 446-448). It has not furnished fossils but is considered to be Cretaceous because of its lithologic resemblance to the Shaktolik group.

30. The Koyukuk group (Martin, 1926, pp. 442-444) has furnished aucellas of Valanginian age including A. sublaevis Keyserling (Mes. loc. 2180) and A. cf. A. crassicollis Keyserling (Mes. locs. 2178, 2181).

31. The 8000 to 10,000 feet, or more of sedimentary rocks comprising the Shaktolik group in the lower Yukon Valley have previously been referred to the lower part of the Upper Cretaceous mainly on the basis of plant fossils (Martin, 1926, pp. 424-429; Hollick, 1930, pp. 5-8; Martin in Hollick, 1930, pp. 31, 32). This age determination has been based on the identity of many species with species in the Dakota sandstone. In addition 3 species have been recorded previously from the Raritan formation (Cenomanian) and 5 from the Magothy formation (Coniacian) of the Atlantic Coast. Also, 2 species have been recorded from the Laramie formation. The age evidence indicated by these species from the Magothy and Laramie formations has been more than balanced by the presence of 12 species of Early Cretaceous age, even though Hollick (1930, p. 5) does not state what stages of the Lower Cretaceous are represented. In general, therefore, assignment of the plant-bearing beds of the Shaktolik group to the early Late Cretaceous has seemed reasonable under the assumption that the Dakota sandstone is of Cenomanian age. This assignment has been partially supported by preliminary determinations of the marine mollusks by Stanton (in Martin, 1926, pp. 412-416).

Recent studies of marine mollusks confirm the correlation of the Shaktolik group with the plant-bearing parts of the Dakota sandstone of Kansas, Iowa, South Dakota and North Dakota but shows that both the Shaktolik group and the Dakota sandstone in the states mentioned are of Albian rather than Cenomanian age. This age determination is based mainly on the presence of the ammonite Gastroplites in the Nulato formation (Mes. locs. 2678, 2926, 2927, 21418) of the Shaktolik group and in the Mowry shale which overlies the Dakota sandstone. The significance of Gastroplites and the similar Neogastroplites in the Mowry shale in the United States has been discussed by Cobban and Reeside (1951, pp. 1892, 1893). Gastroplites in England has been found at the top of the middle Albian (Spath, 1937, pp. 257-260). Gastroplites in California is represented by G. crossi (Anderson) and G. stantoni (Anderson) (not McLearn) (Anderson, 1938, p. 196) which occur near the top of the Horsetown formation associated with other ammonites of middle Albian age. The position of Gastroplites in the Mowry shale cannot be lower than upper Albian because the Mowry overlies the

Skull Creek shale which is in part the northern extension of the Kiowa shale of Kansas and the Kiamichi formation of Texas, both of which contain late middle Albian ammonites. The position of Neogastroplites is definitely above that of Gastroplites in the western interior of Canada (McLearn, 1945, p. 11, fig. 1) and is probably above that of some species of Gastroplites in the western interior of the United States. In Canada Neogastroplites has been dated tentatively as late Albian on the basis of stratigraphic position, but the possibility of it ranging into the Cenomanian cannot be excluded. However, in the United States the entire Cenomanian seems to be present in the beds overlying the Mowry shale (Cobban and Reeside, 1951, p. 1893; Cobban, 1951, p. 2197). At most Neogastroplites could not be younger than early Cenomanian. If Neogastroplites represents the latest Albian then the range of Gastroplites would be middle Albian to early late Albian.

Concerning the age of the Shaktolik group, therefore, the presence of Gastroplites in the Nulato formation is evidence that that formation is not younger than early late Albian. The species present, G. aff. G. allani McLearn (Mes. locs. 2926, 2927, 21418) and G. stantoni McLearn (not Anderson) Mes. loc. 2678), are quite different from the species in the Mowry shale and resemble species from California and northern Alaska that are of early middle Albian age (see annotations 1, 14, 46). Such an age is also indicated by two ammonites probably belonging to Cleoniceras (Mes. loc. 21418), which genus is not known above the early middle Albian. As the adjoining Melozi and Kaltag formations contain many plant species in common, they are probably about the same age as the Nulato formation. The reported thickness of the Kaltag formation is so much less than the Nulato that it probably does not represent as much time and may not be younger than the middle Albian. Likewise the Melozi formation probably represents only a small part of the middle Albian. This is indicated by the fact that its flora is quite distinct from that in the Lemuroceras beds in the lower part of the Kennicott formation of the Chitina Valley (see annotation 14) or in the Lemuroceras-bearing Torok formation of northern Alaska. The Lemuroceras beds have furnished a variety of mollusks which can be dated confidently as lower Albian to early middle Albian. Considering that the plants in the Lemuroceras beds have been compared by paleobotanists with Jurassic and earliest Cretaceous plants of California and other areas, there must have been a marked change in the Alaskan flora during middle Albian time.

32. The Ungalik conglomerate comprises several thousand feet of conglomeratic beds, appears to underlie the Shaktolik group conformably and is considered to be of about the same age (Martin, 1926, p. 412), although it has not furnished determinable fossils. Until the formation has been more thoroughly studied, the possibility exists that it may be at least partly of Neocomian age, as such strata have been identified to the north in the Koyukuk Valley and to the southwest in the Kuskokwim region.

33. The presence of beds corresponding to the Coniacian stage of the middle Late Cretaceous is based on a collection of Inoceramus vancouverensis Shumard from the northwest side of the Innoko River about 30 miles airline above the confluence of the Innoko and Iditarod Rivers (Mes. loc. 13430). The age significance of this species is discussed under Annotation 35.

34. There is no reliable fossil evidence for the age of thousands of feet of sandstone and shale overlying the Paleozoic rocks in the Innoko and Iditarod Valleys and in the upper Kuskokwim Valley. Some specimens of Inoceramus from these beds are too poorly preserved for specific identification. The apparent radial folds on specimens from Mes. loc. 7823 could be a result of crushing. One collection (Mes. loc. 12561) obtained near the head of the Nowitna River on the southern margin of the Ruby district contains a number of belemnites and fragments of a large species of Inoceramus. The presence of belemnites suggests that the beds containing them are of Early Cretaceous or Jurassic age because belemnites are rare in the Upper Cretaceous of Alaska and in the western interior of North America. The presence of a large species of Inoceramus suggests an Albian or later Cretaceous age, although a few large Inoceramus have been found in the Upper Jurassic of North America.

35. Upper Cretaceous graywacke and siltstone estimated to be between 30,000 to 65,000 feet thick cover large areas in the Kuskokwim region as far northeast as the Stony River in the Georgetown district (Personal communication from J. M. Hoare and W. M. Cady). These rocks have furnished many Inoceramus and a few ammonites that prove that the Cenomanian and Coniacian stages are represented. Some of the species of Inoceramus may represent the Turonian or Santonian stages. The Inoceramus of Coniacian age occur mostly in sediments that are interbedded with andesitic volcanics in the lower part of the Kuskokwim region.

The Cenomanian is represented by Inoceramus dunveganensis McLearn (Mes. locs. 9087, 18646, 18866, 19390, and 19732) and I. athabaskensis McLearn (Mes. loc. 19388 and probably 18928 and 19392). I. dunveganensis has been found elsewhere in the Dunvegan formation of Alberta and British Columbia (McLearn, 1945, p. 3). I. athabaskensis occurs in both the Dunvegan formation and in the basal part of the slightly younger La Biche formation below beds containing the ammonite Watinoceras and Inoceramus labiatus Schlotheim of early Turonian age (McLearn, 1943, pp. 37, 44). An association of I. nahwisi McLearn with I. athabaskensis at Mes. loc. 19388 is interesting because I. nahwisi has been reported previously only from the Neogastroplites beds of Canada (McLearn, 1945, pp. 11, 12) and the United States (Cobban, 1951, p. 2181). These Neogastroplites beds are either of latest Albian or early Cenomanian age and are distinctly older than the Dunvegan formation. The Cenomanian age of the Dunvegan formation is based not only on its stratigraphic position but on the presence of species of the ammonite Dunveganoceras identical with species in the lower part of the Greenhorn formation of the United States whose age is well-established.

Some of the species of Inoceramus from the Kuskokwim region might be either Cenomanian or Turonian. One species (Mes. locs. 9226 and 18926) is similar to I. reachensis Etheridge (Woods, 1911, p. 278, pl. 48, figs. 4, 5, pl. 49, fig. 1) from the Cenomanian of England. It is associated with Scaphites (Mes. loc. 18926) having evolute septate coils which occur in beds ranging in age from late Albian to early Turonian and do not occur again until near the end of the Cretaceous. Another species of Inoceramus (Mes. loc. 20718) is similar to I. corpulentus McLearn which occurs in the Dunvegan formation and the younger Kaskapau and Blackstone formations of Alberta and British Columbia. Most of its reported occurrences are from beds of Turonian age.

The Coniacian stage is almost certainly represented by Inoceramus cf. I. uwajimensis Yehara and an associated ammonite Parapuzosia (Mes. loc. 20717). The Inoceramus is identical with a species in the lower few hundred feet of the Matanuska formation, which has furnished considerable evidence for a Coniacian age (See Annotation 15). The Coniacian stage is probably also represented by Inoceramus vancouverensis Shumard (Whiteaves, 1879, p. 170, pl. 20, figs. 4, 4a, b) (Mes. locs. 13430, 20716, 21033, 21481) and by an associated ammonite Scaphites cf. S. impendicostatus Cobban (Mes. loc. 20716). The later species (Cobban, 1951, p. 28, pl. 11, figs. 1-14) is characterized by peculiar flattened, somewhat overhanging ribs on the sutured part of its shell, a feature unknown in any other species of Scaphites. It occurs in rocks equivalent to the basal part of the Niobrara formation which can be correlated definitely with the basal part of the Coniacian stage.

Some evidence concerning the age of Inoceramus vancouverensis Shumard is shown by its occurrence in the southern part of Vancouver Island near the base of the Nanaimo group in the same coal-bearing sequence that has furnished Inoceramus undulatoplicatus Roemer (Whiteaves, 1879, pp. 168, 171; 1903, pp. 348, 351, 397). The fossil-bearing part of this sequence is now included in the Haslam formation (Ushur, 1952, pp. 9-11) and is correlated by Ushur (1952, pp. 36-38) with the Campanian stage, with reservations. Of the ammonites present Pseudoschloenbachia indicates an age not older than Santonian, Hauericeras and Canadoceras indicate an age not older than the Coniacian, and the species present are comparable to species of Coniacian to Campanian age in other parts of the world. Six of the species of ammonites range up into younger formations but the range of the species within the Haslam formation is not discussed (Ushur, 1952, p. 37). The age significance of Inoceramus undulatoplicatus as a nearly world-wide marker near the Coniacian Santonian boundary was not mentioned by Ushur and was probably not realized by him. A suggestion that Inoceramus vancouverensis actually underlies I. undulatoplicatus within the Haslam formation is furnished in a statement by Ushur (1952, p. 11) that "Inoceramus cf. schmidti is found abundantly on Brannen Creek and from the upper part of the formation between Nanoose Bay and Blunden Point, and I. ex gr. subundatus Meek is common in most other parts of the formation."

Concerning this statement, it is inferred that Inoceramus cf. schmidti is identical with Inoceramus undulatoplicatus Roemer and that I. ex gr. subundatus includes I. vancouverensis Shumard. If the superposition of I. undulatoplicatus over I. vancouverensis is valid, then the Haslam formation probably includes beds of Coniacian age. It is probably significant that species similar to I. vancouverensis in the Western Interior and in the Gulf region of the United States occur at a lower level than I. undulatoplicatus, in beds that are correlated with the lower Coniacian.

The volcanics and associated sediments that are herein considered to be of Coniacian age are reported by Joseph Hoare (personal communication dated March 4, 1953) to rest with probable unconformity on rocks of Cenomanian age.

Upper Cretaceous sedimentary rocks younger than the Coniacian may exist in the central Kuskokwim region, but the faunal and stratigraphic evidence is meager.

36. The Albian is probably represented in the lower Kuskokwim region by thick masses of conglomerate that are interbedded with and grade laterally into graywacke and siltstone. These conglomeratic sediments overlie beds of Valanginian age and are overlain by beds of Cenomanian or locally of Coniacian age. The evidence for an Albian age consists mainly of a small species of Inoceramus (Mes. locs. 21476 and 19395B) characterized by an extended posterior wing, prominent concentric ribbing of approximately equal strength, and a weak sulcus on its posterior side. The ribbing is rather similar to that of I. neocomiensis d'Orbigny (1846, p. 503, pl. 303, figs. 1, 2; Woods, 1911, p. 262, pl. 45, figs. 1, 2) or of I. ewaldi Schluter (Wollemann, 1906, p. 272, pl. 6, fig. 9) from the Aptian and lower Albian of northwest Europe. The extended posterior wing is similar to that on I. neocomiensis var. alata Schmidt (1872, p. 160, pl. 3, figs. 9a, b, text-fig. 10a, b) from northern Siberia. None of these Eurasian forms have a sulcus on the posterior side.

The Albian age of the species of Inoceramus in question from the lower Kuskokwim is based on probable identity with a specimen from northern Alaska at Mes. loc. 20399 at the top of the Lower Cretaceous sequence. This specimen is associated with Inoceramus anglicus Woods, a middle and upper Albian marker. It is in a lithologic unit whose upper part has furnished Gastroplites and Cleoniceras, and is correlated with the lower part of the middle Albian substage.

37. Beds of Valanginian age have been identified faunally in the lower and central Kuskokwim region west of the Holitna Valley in the upper part of 15,000 feet, or more of graywacke, siltstone, chert, volcanics, and very minor amounts of limestone. The evidence consists of Aucella crassicollis Keyserling (Mes. locs. 19730, 21473, 23166), A. cf. A. crassicollis Keyserling (Mes. locs. 21474, 21475, 23163, 23167, 23169), and A. sublaevis Keyserling (Mes. loc. 23171). The Berriasian has not been identified. The underlying beds include Upper Jurassic at least locally, because at one place (Mes. loc. 20714) about 28 miles S. 8° W. of Aniak in the Akiak District were obtained specimens of Aucella mosquensis (von Buch) and A. rugosa (Fischer). Much of the thick sequence below the Valanginian is of Late Triassic age. In places the Cretaceous strata rest on gneiss and schist that are probably pre-Cambrian, or at least much older than nearby exposures of Devonian limestone (personal communication from J. M. Hoare, Dec. 5, 1952).

38. An enormous thickness of beds in the Nushagak Valley and Nushagak Hills has been mapped by Mertie (1938, pp. 48-61) as probably Cretaceous, although the paleontologic evidence consists only of a few fragments of indeterminable Inoceramus. The presence of Upper Cretaceous strata has been established, however, by Wallace M. Cady by actually tracing from the central Kuskokwim Valley southward into the valleys of the Nushagak and Mulchatna Rivers (personal communication from W. M. Cady).

39. The presence of the Bergman group in the Kobuk Valley of northern Alaska is based on mapping westward from the upper part of the Koyukuk Valley (Mendenhall, 1902, pp. 39-42; Smith, 1913, pp. 284-286) and not on fossil evidence.

40. Not much more is known about the Cretaceous sequence on Cape Lisburne than was summarized by Martin in 1926 (pp. 455-467). Recently geologists mapping in the western part of the Wainwright district have noted that the upper part of the Torok formation and the Nanushuk group become less marine westward toward Cape Lisburne, as shown by a decrease in the number of marine organisms, an increase in plant-bearing beds, and by lithologic changes. Aerial photographs indicate that beds equivalent to the Torok and Nanushuk are present in the northern part of Cape Lisburne, but the exact correlation of these units with the Corwin formation as described by Schrader (1902, p. 244, 245; 1905, p. 72-74) and Collier (1906, p. 16, 27-30, 36-42) is not known. Certainly some of the plants from the Corwin formation (Martin, 1926, p. 461) indicate a correlation with the lower part of the Kennicott formation of the Chitina Valley. This part contains many ammonites and pelecypods that are of early to middle Albian age and that are identical with or similar to species in the Torok formation of northern Alaska.

41. The Valanginian has been identified on the Kivalina River in the southern part of Cape Lisburne on the basis of Aucella sublaevis Keyserling (Mes. loc. 13716). The beds in which these fossils occur are a southwestward continuation of the Okpikruak formation in the De Long Mountains.

42. The term "Nanushuk group, undifferentiated," is useful in areas that have not been thoroughly studied or in which outcrops are few. In such areas the lithological characteristics of the group are essentially the same as in the foothills of the Brooks Range between the Killik and Anaktuvuk Valleys.

43. The middle and upper parts of the Torok formation have furnished Albian ammonites belonging to Lemuroceras, Cleoniceras, and Beudanticeras. Beudanticeras has been found at seven localities and is associated with Lemuroceras at one and with

Cleoniceras at one. Cleoniceras has been found at eight localities, and Lemuroceras at eight localities. Lemuroceras has not been found with Cleoniceras, although the stratigraphic positions of the various collections show that the lowest occurrence of Cleoniceras is below the highest occurrence of Lemuroceras. Besides these ammonites, the only other fossil of known stratigraphic significance is the pelecypod Aucellina dowlingi McLearn which occurs in the upper part of the Torok formation some 1500 feet above the lowest occurrence of Lemuroceras.

The Torok formation is dated as early Albian because it underlies beds that are probably not younger than early middle Albian and because it contains Lemuroceras and Aucellina similar to species in the lower part of the Kennicott formation of the Chitina Valley. This part can be correlated with certain zones in the upper part of the Horsetown formation of California (see Annotation 14). Judging from the distribution of Lemuroceras in the Kennicott and Horsetown formations, it ranges from the top of the lower Albian (zone of Leymeriella tardefurcata) into the lower part of the middle Albian (zone of Douvilleiceras mammillatum) but is most common in the lower Albian. Cleoniceras has the same known range but is most common at the top of the Leymeriella tardefurcata zone, according to Spath (1943, pp. 687, 699). In Madagascar (Collignon, 1949, pp. 102, 109) Cleoniceras and Lemuroceras are associated in beds that are correlated with the Douvilleiceras mammillatum zone, but Lemuroceras is more common than Cleoniceras. In northern Alaska Cleoniceras ranges into and becomes fairly common in the Tuktu member of the Umiat formation, in which Lemuroceras has not been found. This common non-association of the two genera suggests that they occupied slightly different ecological niches and that either genus may be abundant locally during late lower Albian and early middle Albian. Considering that the time represented is only a small part of the Albian stage, it is interesting that the Torok formation ranges in thickness from 6,000 to 10,500 feet and the Tuktu member of the Umiat formation from 1,000 to 2,500 feet in the area between the Killik and Anaktuvuk Rivers.

It is doubtful whether the Torok formation includes beds older than Albian. In some sections the basal part of the Torok has not furnished fossils, but considering the rapidity of sedimentation, this part need not represent more than the zone of Acanthoplites nodosocostatum of the basal Albian of Europe.

The Torok formation thins eastward from the Sagavanirktok Valley to the Shaviovik Valley and is absent east of the latter. This thinning is ascribed to onlap against a structural high in the area between the Shaviovik and Sadlerochit Valleys (personal communication from A. S. Keller and R. L. Detterman).

44. The Okpikruak formation corresponds with the Berriasian and Valanginian stages on the basis of aucellas identical with species in northern Eurasia. Its basal few hundred feet includes Aucella okensis Pavlow and A. subokensis Pavlow, which are characteristic of the beds at the Jurassic-Cretaceous boundary. With these are species that probably belong to A. terebratuloides Lahusen and A. surensis Pavlow. Both of these range from the latest Jurassic into the Berriasian but are more common in the latter.

Most of the Okpikruak formation is of Valanginian age. Above the beds characterized by A. okensis and A. subokensis occur numerous A. sublaevis Keyserling. With these may be associated A. crassa Pavlow, or rarely A. crassicollis Keyserling. The latter, however, is more common at higher levels in the middle and upper parts of the formation. As A. crassicollis is reported to attain its greatest abundance in the middle Valanginian (Pavlow, 1907, p. 77), the beds in northern Alaska having abundant A. sublaevis are probably lower Valanginian.

There is no faunal evidence in all of Alaska for the presence of rocks representing the Hauterivian, Barremian, and Aptian stages, although the Aptian may be represented locally in the Torok formation beneath beds containing Lemuroceras and Cleoniceras. During these stages Alaska was emergent and was subjected at least locally to mountain-building movements before Albian time. Orogeny culminated probably during the Barremian because, as noted by Maync (1949, p. 242), there is no evidence for the presence of the Hauterivian or Barremian stages anywhere in the Arctic region. By Aptian time, however, the seas were again encroaching on the lands, as shown by the presence of beds of that age in East Greenland (Frebold, 1935; Maync, 1949, pp. 258-270) and in Spitzbergen (Frebold and Stoll, 1938, p. 75, 76). Possibly the shrinking of the Arctic Ocean during the Barremian has some bearing on the near extinction of ammonites at that time.

The orogenic movements during Hauterivian and Barremian time resulted in differential erosion of the Okpikruak formation. This is particularly evident in the area between the Sagavanirktok and the Canning Valleys where the formation thins from a maximum of 1560 feet to less than 200 feet and is locally absent (personal communication from A. S. Keller and R. L. Detterman). The easternmost exposure is about two miles west of the Canning River. No trace of the Okpikruak formation has been found along the banks of the Canning River or in the area to the east, although exposures there are excellent. Fossil collections from the Okpikruak formation between the Sagavanirktok and Canning Valleys contain mostly Aucella okensis Pavlow and Aucella subokensis Pavlow of Berriasian age. Aucella crassicollis Keyserling was found only at one locality near the Sagavanirktok River. Aucella sublaevis Keyserling was found only at two widely separated localities. The fossil evidence indicates, therefore, that the thinning of the Okpikruak formation is due to erosion and not to onlap against a structural high.

45. Correlations of the various members, tongues, and formations of the Colville group is based partly on mollusks and foraminifera and partly on interpretations of the intertonguing relationships of dominantly nonmarine or brackish water sequences on the south with mostly normal marine sequences in the Arctic Coastal Plain (Payne, Gryc, Tappan et al, 1951: Gryc, Patton, Payne, 1951, pp. 164-167). At the base the Seabee member of the Shrader Bluff formation contains such mollusks as Scaphites delicatulus Warren, Watinoceras, and Inoceramus labiatus (Schlotheim), which are of early Turonian age. The overlying Tuluga member contains Inoceramus similar to I. lundbreckensis McLearn and to I. cardissoides Goldfuss and species of Scaphites which indicate a correlation with the upper part of the Santonian and the lower part of the Campanian stages. The still higher Sentinel Hill member is correlated by means of foraminifera with the lower part of the Riding Mountain formation of Manitoba and the Lea Park shale of Alberta, which are equivalent to the lower part of the Pierre shale in the western interior of the United States. The Sentinel Hill member is absent in the foothills north of the Brooks Range and probably was never deposited there.

Unconformities based on physical criteria occur both above and below the Seabee member of the Shrader Bluff formation (personal communication from Thomas Payne and George Gryc). The unconformity below the Seabee member cannot represent more than a minor part of the Cenomanian. The unconformity between the Seabee member and the Tuluga member could represent any part, or all, of the late Turonian, Coniacian, or early Santonian. However, part of that time is represented by 720 to 1260 feet of nearly unfossiliferous beds at the base of the Tuluga member below the lowest occurrence of Inoceramus lundbreckensis McLearn. Also, the fact that marine trangression occurred in western, southwestern, and southcentral Alaska in Coniacian time, suggests that the initial deposits of the Tuluga member were formed at that time.

46. The Nanushuk group consists of an essentially nonmarine or brackish water sequence on the south, called the Chandler formation, and a normal marine sequence on the north, called the Umiat formation. These intertongue to some extent in the foothills of the Brooks Range, but particularly in the area near Umiat and along the upper course of Ikpikpuk River.

At the base of the Nanushuk group in the Colville Valley is about a thousand feet of marine sandstone, the Tuktu member of the Umiat formation, that is assigned to the basal part of the middle Albian on the presence of Cleoniceras and Inoceramus anglicus Woods. The latter is not known below the middle Albian and Cleoniceras has not been found above the Douvilleiceras mammillatum zone of the basal middle Albian. This age determination is based partly on the presence of Cleoniceras and Lemuroceras in the underlying Torok formation, which indicate an age for that formation not older than the later part of the early Albian.

The Hatbox tongue overlying the Tuktu member ranges from 1000 to 3000 feet in thickness, is mostly nonmarine, but has furnished a few marine fossils of Albian age. These include Inoceramus anglicus Woods and many other pelecypods identical specifically with pelecypods in the Tuktu member. Most of these pelecypods appear to be undescribed species but some may be identical with species in the Lemuroceras beds of Canada (McLearn, 1945, pls. 3-5). Other fossils include starfish arms and imprints and the ammonites Cleoniceras and Gastroplites. The presence of Cleoniceras is evidence for an early middle Albian age. The Gastroplites present resemble G. allani McLearn (1933, pp. 18, 19, pl. 1, figs. 6-8) which occurs in the Western Interior of Canada in beds somewhat higher than those containing Lemuroceras. The range of Gastroplites has been discussed in annotations 1, 14, and 31 and it has been shown that species identical or similar to G. allani and G. stantoni McLearn occur in the lower Yukon and in California with other ammonites that have not been recorded above the early middle Albian. These fossils show, therefore, that at least part of the Hatbox tongue is of early middle Albian age. If Mes. loc. 20484, which has furnished both Cleoniceras and Gastroplites, is actually from the top of the Hatbox tongue as reported by the collector, then the Hatbox tongue does not include all of the middle Albian.

At the top of the Nanushuk group in the foothills of the Brooks Range abundant Inoceramus have been found in marine intercalations in the Niakogon tongue of the Chandler formation. The common species include I. athabaskensis McLearn and I. dunveganensis McLearn. These have been identified elsewhere in Alaska in the lower part of the Upper Cretaceous sequence in the Kuskokwim region (see annotation 36). In northwestern Alberta and northeastern British Columbia they are associated with the ammonite Dunveganoceras in the Dunvegan formation. I. athabaskensis likewise occurs at the base of the La Biche shale on the Athabaska River. All the occurrences in Canada are in beds that underlie the lowest ammonite zone of the Turonian, which zone has been identified in northern Alaska at the base of the Shrader Bluff formation immediately above the Nanushuk group. The stratigraphic position of Dunveganoceras in Montana, Canada, and England is upper Cenomanian, according to present information.

An unconformity between the Hatbox tongue and the Niakogon tongue amounting to part of the middle Albian, all of the upper Albian and part of the Cenomanian is shown by the fossils in these tongues. The absence of upper Albian is not surprising, as the only definite upper Albian in Alaska identified by marine fossils is in the Chitina Valley (see annotation 14). Failure to identify upper Albian rocks in northern Alaska as well as in East Greenland (see annotation 1) suggests a withdrawal of the sea from the northern part of North America during late Albian time. Against this interpretation is the presence of the Neogastroplites beds in the western interior of Canada and the United States which beds are considered to represent a marine invasion from the north during the late Albian. It is possible that the unconformity between the Hatbox tongue and the Niakogon tongue did not extend far basinward and that there was little, if any, interruption in sedimentation in the area along the present Arctic Coast. The extent and character of the unconformity will have to be determined by additional subsurface studies.

47. The Ignek formation comprises two members, according to recent field work by A. S. Keller and R. H. Morris of the Geological Survey. The lower member consists of a sandstone unit about 200 feet thick and an overlying black shale unit about 260 feet thick. The sandstone unit rests on the Okpikruak formation of Berriasian age two miles west of the Canning River and on the Kingak shale of upper Oxfordian age along the Canning River and in Ignek Valley to the east. The sandstone unit contains poorly preserved pelecypods belonging to long-ranging genera. The overlying shale unit contains a microfauna identical with that in the Tuktu member and the Hatbox tongue at the base of the Nanushuk group (personal communication from Harlan Bergquist).

The upper member of the Ignek formation is much thicker than the lower member, contains bentonitic beds, and resembles lithologically parts of the Colville group younger than the Seabee member. It contains a microfauna identical with that in the Tuluga member of the Colville group (personal communication from Harlan Bergquist). This correlation is confirmed by the discovery of a squid which Reeside considers identical with Teusoteuthis longus Logan from the upper part of the Niobrara formation of Kansas.

REFERENCES TO THE CRETACEOUS OF GREENLAND

Aldinger, Hermann (1935) Geologische Beobachtungen im oberen Jura des Scoresbysundes (Ostgrönland), Meddelelser om Grønland, Bind 99, nr. 1, 128 pages, 3 pls., 35 figs.

Bell, W. A. (1944) Use of some fossil floras in Canadian stratigraphy, Trans. Roy. Soc., Canada, 3rd ser., vol. 38, sec. 4, pp. 1-13.

Berry, E. W. (1911) The Lower Cretaceous floras of the World, in Lower Cretaceous deposits of Maryland, Maryland Geological Survey, Lower Cretaceous, pp. 99-151.

________ (1929) The Kootenay and Lower Blairmore Floras, Canada, Nat. Mus. Bull. 58, pp. 28-54, 5 pls.

Bøgvad, Richard and Rosenkrantz, Alfred (1934) Beiträge zur Kenntnis der untern Kreide Ostgrønlands, Meddelelser om Grønland, Bind 93, nr. 1, 28 pages, 3 pls., 1 fig.

Brown, Roland (1946) Fossil plants and Jurassic-Cretaceous boundary in Montana and Alberta, Am. Assoc. Petrol. Geol., Bull. vol. 30, no. 2, pp. 238-248.

Cobban, W. A. (1951a) Colorado shale of central and northwestern Montana and equivalent rocks of Black Hills, Am. Assoc. Petrol. Geol., Bull., vol. 35, no. 10, pp. 2170-2198, 2 figs.

________ and Reeside, J. B. Jr. (1951) Lower Cretaceous ammonites in Colorado, Wyoming and Montana, Am. Assoc. Petrol. Geol., Bull., vol. 35, no. 8, p. 1892, 1893.

Collignon, Maurice (1949) Recherches sur les faunes Albiennes de Madagascar. I - L'Albien d'Ambarimaninga (Madagascar), Ann. Géol. Serv. des Mines de Madagascar, 128 pages, 22 pls., 29 figs.

Donovan, D. T. (1949) Observations on the Mesozoic rocks of Geographical Society Ø, East Greenland, Meddelelser om Grønland, Bind 149, nr. 5, pp. 3-13, 7 figs.

Frebold, Hans (1934) Obere Kreide in Ostgrönland, Meddelelser om Grønland, Bind 84, nr. 8, 32 pages, 4 pls., 11 figs.

________ (1935) Marines Aptien von der Koldewey Insel (nördliches Ostgrönland): Meddelelser om Grønland, Bind 95, nr. 4, 112 pages, 8 pls., 20 figs.

Heer, Oswald (1883) Ueber die fossile Flora von Grönland, Bot. Jahrb. (Engler), Band 4, pp. 367-385.

Heinz, Rudolf (1928) Das Inoceramen profil der oberen Kreide Lüneburgs, 21 Jahrb. Niedersächs. Geol. Ver. Hannover, pp. 65-81, pls. 2, 3.

Humphrey, William E. (1949) Geology of the Sierra de los Muertos area, Mexico (with descriptions of Aptian cephalopods from the La Peña formation), Geol. Soc. Am. Bull., vol. 60, pp. 89-176, pls. 1-18, 2 figs.

Kilian, W., and Reboul, P. (1915) Contribution à l'étude du faunes paléocretacées du Sud-Est de la France. I - La faune de l'Aptian inférieur des environs de Montélimar (Homme d'Armes) (Drôme), pp. 1-221, pls. 1-9, 10 figs.

Loriol, P. de (1893) Om fossile Saltvandsdyr fra Nord-Grønland, Meddelelser om Grønland, Bind 5, pp. 203-213.

McLearn, F. H. (1945) Revision of the Lower Cretaceous of the western interior of Canada (2nd edition), Canada Geol. Survey Paper 44-17, 14 pp., 2 tables.

Madsen, Victor (1897) The genus Scaphites in West Greenland, Medd. fra Dansk Geol. Foren, nr. 4, Kobenhavn.

Maync, Wolf (1949) The Cretaceous beds between Kuhn Island and Cape Franklin (Gauss Peninsula), northern East Greenland, Meddelelser om Grønland, Bind 133, nr. 3, 291 pages, 4 pls., 70 figs.

Ravn, J. P. J. (1918) De marine Kridtaflejeringer i Vest-Grønland og deres Fauna, Meddelelser om Grønland, Bind 56, pp. 309-366, illus.

Roch, E. (1927) Étude stratigraphique et paléontologique de l'Aptian inférieur de la Bedoule (pres Cassis) (Bouches-du-Rhône), Mém. Soc. géol. France, N.S., vol. 4, fasc. 1, mém. 8, 37 pages, pls. 1-4.

Riedel, L. (1937) Estudios geológicos y paleontológicos sobre la Cordillera Oriental de Colombia. Pt. II, Amonitas del cretácico inferior de la Cordillera Oriental, Dept. de Minas y Petr., Minist. de Ind. y Trab., pp. 7-80, pls. 3-14.

Rosenkrantz, Alfred (1942) The marine Cretaceous sediments at Umivik, pp. 37-42 in A geological reconnaissance of the southern part of the Svartenhuk Peninsula, West Greenland, Meddelelser om Grønland, Bind 135, nr. 3, 72 pages, 5 pls., 32 figs.

Spath, L. F. (1930) On some Ammonoidea from the Lower Greensand, Annals and Mag. Nat. Hist., 10th ser., vol. 5, pp. 419-464, pls. 14-17.

________ (1937) The Canadian ammonite genus Gastroplites in the English Gault, Annals and Mag. Nat. Hist., 10th ser., vol. 19, pp. 257-260, 1 fig.

________ (1946) Preliminary notes on the Cretaceous ammonite faunas of East Greenland, Meddelelser om Grønland, Bind 132, nr. 4, 12 pages.

________ (1947) Additional observations on the invertebrates (chiefly ammonites) of the Jurassic and Cretaceous of East Greenland. I - The Hectoroceras fauna of southwest Jameson Land, Meddelelser om Grønland, Bind 132, nr. 3, pp. 3-70, 5 pls., 8 figs.

Stauber, Hans (1938) Stratigraphische Untersuchungen postdevonischer Sedimente aus den Inseln Traill und Geographical Society, Medellelser om Grønland, Bind 114, nr. 1, pp. 21-28, 2 pls.

White, David and Schuchert, Charles (1898) Cretaceous series of the west coast of Greenland, Geol. Soc. Amer. Bull., vol. 9, pp. 343-368, pls. 24-26.

Whitehouse, F. W. (1926) The Cretaceous ammonoidea of eastern Australia, Mem. Queensland Mus., vol. 8, pt. 3, pp. 195-242, pls. 34-41.

REFERENCES TO THE CRETACEOUS OF ALASKA

Adkins, W. S. (1933) The Mesozoic systems in Texas in The geology of Texas, vol. 1, Stratigraphy, Univ. Texas Bull. 3232, pt. 2, p. 239-518.

Anderson, F. M. (1902) Cretaceous deposits of the Pacific Coast, Calif. Acad. Sci. Proc., 3rd ser., vol. 2, no. 1, p. 1-154, 12 pls.

________ (1938) Lower Cretaceous deposits in California and Oregon, Geol. Soc. Am., Special Paper 16, 339 pages, 85 pls., 6 figs.

________ (1941) Synopsis of the later Mesozoic in California, California Dept. Nat. Res., Div. Mines Bull. 118, pt. 2, p. 183-186, 2 figs.

________ (1945) Knoxville series in the California Mesozoic, Geol. Soc. Am. Bull., vol. 56, p. 909-1014, 15 pls.

________, and Hanna, G. D. (1935) Cretaceous geology of Lower California, Calif. Acad. Sci. Proc., 4th ser., vol. 23, no. 1, p. 1-34, pls. 1-11, 2 figs.

Arkell, W. J. (1946) Standard of the European Jurassic, Geol. Soc. Am. Bull., vol. 57, pp. 1-34.

Atwood, W. W. (1911) Geology and mineral resources of parts of the Alaska Peninsula, U. S. Geol. Survey Bull. 467, 137 pages, maps.

Bogoslowsky, N. A. (1902) Materialien zur kenntniss der Untercretacischen Ammonitenfauna von Central and Nord-Russland, Mém. Com. géol. Russie, [NS], no. 2, 161 pages, pls. 1-18.

Capps, S. R. (1916) The Chisana - White River district, Alaska, U. S. Geol. Survey Bull. 630, 130 pages, maps.

________ (1927) Geology of the upper Matanuska Valley, Alaska, U. S. Geol. Survey Bull. 791, 92 pages, 5 figs., 16 pls.

________ (1933) The eastern portion of Mount McKinley National Park, U. S. Geol. Survey Bull. 836, p. 219-300, 3 figs., map.

________ (1940) Geology of the Alaska Railroad region, U. S. Geol. Survey Bull. 907, 201 pages, 10 pls., geol. maps.

Cobban, W. A. (1951a) Colorado shale of central and northwestern Montana and equivalent rocks of Black Hills, Am. Assoc. Petrol. Geol. Bull., vol. 35, no. 10, p. 2170-2198, 2 figs.

________ (1951b) Scaphitoid cephalopods of the Colorado group, U. S. Geol. Survey Prof. Paper 239, 42 pages, 21 pls.

________, and Reeside, J. B., Jr., (1951) Lower Cretaceous Ammonites in Colorado, Wyoming, and Montana, Am. Assoc. Petrol. Geol. Bull., vol. 35, no. 8, pp. 1892-1893.

Collier, A. J. (1906) Geology and coal resources of the Cape Lisburne region, Alaska, U. S. Geol. Survey Bull. 278, 54 pages, map.

Collignon, Maurice (1949) Recherches sur les faunes Albiennes de Madagascar I - L'Albien D'Ambarimaninga (Madagascar). Ann. Géol. Serv. des. Mines de Madagascar, vol. 16, 119 pages, 22 pls.

Frebold, H. and Stoll, E. (1937) Das Festungsprofil auf Spitzbergen. III. Stratigraphie und Fauna des Jura und der Unterkreide, Skrifter om Svalbard og Ishavet, no. 68, 85 pages, 1 pl., Oslo.

Gryc, G., Patton, W. W., and Payne, T. G. (1951) Present Cretaceous stratigraphic nomenclature of northern Alaska, Jour. Wash. Acad. Sci., vol. 41, no. 5, pp. 159-167, 3 figs.

Hazzard, J. C. (1950) Lower Cretaceous rocks at Cape Kaguyak north of Kukak Bay, Alaska, Science, vol. 112, p. 227.

________, Bryan, J. J., Borax, E., and Shoemaker, R. (1950) Cretaceous rocks in the Kamishak Bay area, Cook Inlet, Alaska, Science, vol. 112, p. 226.

Heintz, Rudolf (1928) Das Inoceramen-profil der oberen Kreide Lüneburgs, 21 Jahresb. Niedersächs. geol. Ver., Hannover.

Hollick, C. A. (1930) The Upper Cretaceous floras of Alaska, U. S. Geol. Survey Prof. Paper 159, 123 pages, 87 pls. 5 figs.

Jacob, M. C. (1907) Etude sur quelques ammonites du Crétacé moyen, Mém. Soc. géol. France, Paléont., XV, no. 38, pp. 1-64, pls. 1-9.

Jeletzky, J. A. (1950) Stratigraphy of the West Coast of Vancouver Island between Kyuquot Sound and Esperanza Inlet, British Columbia, Geol. Survey Canada Paper 50-37, 52 pages, 1 map, 1 correlation table.

Johnson, B. L. (1916) Copper deposits of the Latouche and Knight Island districts, Prince William Sound, U. S. Geol. Survey Bull. 662, pp. 193-220, 1 map.

Knowlton, F. H. (1914) The Jurassic flora of Cape Lisburne, Alaska, U. S. Geol. Survey Prof. Paper 85, p. 39-55, pls. 5-8.

Martin, G. C. (1926) The Mesozoic stratigraphy of Alaska, U. S. Geol. Survey Bull. 776, 493 pages, 13 figs.

________, and Katz, F. J. (1912) Geology and Coal fields of the lower Matanuska Valley, Alaska, U. S. Geol. Survey Bull. 500, 98 pages, maps.

Matumoto, Taturô (1942, 1943) Fundamentals in the Cretaceous stratigraphy of Japan, Mem. Fac. Science, Kyusyu Imperial University, ser. D., vol. 1, no. 3, Part I, pp. 129-280 (1942), vol. 2, no. 1, Parts II and III, pp. 97-237 (1943).

Maync, Wolf, (1949) The Cretaceous beds between Kuhn Island and Cape Franklin (Gauss Peninsula) northern East Greenland, Meddelelser om Grønland, Bind. 133, nr. 3, 291 pages, 4 pls., 70 figs.

McLearn, F. H. (1933) The ammonoid genera Gastroplies and Neogastroplites, Trans. Roy. Soc. Canada, ser. 3, vol. 27, sec. 4, pp. 13-25, 4 pls.

________ (1940) Preliminary study of some Triassic pelecypods and ammonoids from the Peace River Foothills, B. C., The Canadian Field - Naturalist, vol. 54, no. 8, p. 111-116, pls. 1-4.

________ (1943) Trends in some Canadian Cretaceous species of Inoceramus, The Canadian Field - Naturalist, vol. 57, p. 36-46, 1 table.

________ (1945) Revision of the Lower Cretaceous of the western interior of Canada, (2nd edition), Canada Geol. Survey Paper 44-17, 14 pp., 2 tables.

Mendenhall, W. C. (1902) Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, U. S. Geol. Survey Prof. Paper 10, 68 pages, maps.

Mertie, J. B., Jr. (1930) Geology of the Eagle-Circle district, Alaska, U. S. Geol. Survey Bull. 816, 168 pages, 6 figs., 12 pls.

________ (1937) The Yukon-Tanana region, Alaska, U. S. Geol. Survey Bull. 872, 276 pages, 15 pls., geol. map.

________ (1938) The Nushagak district, Alaska, U. S. Geol. Survey Bull. 903, 96 pages, 12 pls., geol. maps.

Moffitt, F. H. (1918) The upper Chitina Valley, Alaska, U. S. Geol. Survey Bull. 675, 82 pages, maps.

________ (1933) The Suslota Pass district, upper Copper River region, Alaska, U. S. Geol. Survey Bull. 844, p. 137-162, 1 pl. geol. map.

________ (1938) Geology of the Chitina Valley and adjacent area, U. S. Geol. Survey Bull. 894, 137 pages, 16 pls., 1 fig.

________ (1943) Geology of the Nutzotin Mountains, Alaska, with a section on the igneous rocks by R. G. Wayland, U. S. Geol. Survey Bull. 933-B, pp. 103-174, 3 pls., 2 figs., geol. maps.

________, and Capps, S. R. (1911) Geology and mineral resources of the Nizina district, Alaska, U. S. Geol. Survey Bull. 448, 111 pages, map.

________, and Mertie, J. B., Jr. (1923) The Kotsina-Kuskulana district, Alaska, U. S. Geol. Survey Bull. 745, 149 pages, 19 pls., 8 figs.

Nagao, Takumi and Matumoto, Taturô (1939, 1940) A monograph of the Cretaceous Inoceramus of Japan, Jour. Fac. Science, Hokkaidô Imperial University, ser. 4, vol. 4, nos. 3-4, pp. 241-299, pls. 23-34 (1939), vol. 6, no. 1, pp. 1-64, pls. 1-22 (1940).

Orbigny, A. d' (1840-1847) Paléontologie francaise, Terrains Crétacés, 3 vols.

Pavlow, A. P. (1907) Enchaînement des Aucelles et Aucellines du Crétacé Russe, Soc. Imp. Nat. Moscou, Nouv. Mém. vol. 17 (22), p. 1-93, pls. 1-6, correlation table opposite p. 84.

Payne, T. G., Gryc, George, Tappan, Helen, et al. (1951) Geology of the Arctic slope of Alaska, U. S. Geol. Survey Map OM 126, Oil and Gas Inves. Ser., 3 sheets, colored.

Popenoe, W. P. (1943) Cretaceous: East side Sacramento Valley, Shasta and Butte Counties, California, Am. Assoc. Petrol. Geol. Bull., vol. 27, no. 3, p. 306-312, 2 figs.

Schmidt, M. F. (1872) Wissenschaftliche Resultate der zur Aufsuchung eines angekündigten Mammuthcadavers, Acad. Imp. Sciences St. Petersbourg Mem., 7 ser., vol. 18, no. 1, 168 pages, 4 pls., 1 map.

Schrader, F. C. (1902) Geological section of the Rocky Mountains in northern Alaska, Geol. Soc. Am. Bull., vol. 13, p. 233-252.

________ (1904) A reconnaissance in northern Alaska, U. S. Geol. Survey Prof. Paper 20, 139 pages, maps.

Smith, P. S. (1913) The Noatak-Kobuk region, Alaska, U. S. Geol. Bull. 536, 157 pages, maps.

Spath, L. F. (1922) On the Senonian ammonite fauna of Pondoland, Trans. Royal Soc. South Africa, vol. 10, pt. 3, p. 113-147, pls. 5-9.

________ (1923-1943) A monograph of the Ammonoidea of the Gault, 2 vols., illus. Palaeontographical Soc.

________ (1936) The Upper Jurassic Invertebrate Fauna of Cape Leslie, Milne Land. II. Upper Kimmeridgian and Portlandian, Meddelelser om Grønland, Bind 99, nr. 3, 180 pages, 50 pls., 2 figs.

________ (1937) The Canadian ammonite genus Gastroplites in the English Gault, Annals and Mag. Nat. Hist., ser. 10, vol. 19, p. 257-260.

Stoliczka, Ferdinand (1865) The Fossil Cephalopoda of the Cretaceous rocks of northern India - Ammonitidae, Palaeontologia Indica, Mem., series 1 and 3, vol. 1, p. 41-201, pls. 26-94.

Ulrich, E. O. (1904) Fossils and age of the Yakutat formation, Harriman Alaska Expedition, vol. 4, p. 125-146, pls. 11-21.

Usher, J. L. (1952) Ammonite faunas of the Upper Cretaceous rocks of Vancouver Island, British Columbia, Geol. Survey Canada Bull. 21, 182 pages, 31 pls., 4 figs.

Whiteaves, J. F. (1876) On some invertebrates from the coal-bearing rocks of the Queen Charlotte Islands, Canadian Geol. Survey, Mesozoic Fossils, vol. 1, p. 1-92, pls. 1-10, Index map.

________ (1879) On the fossils of the Cretaceous rocks of Vancouver and adjacent islands in the strait of Georgia, Canadian Geol. Survey, Mesozoic Fossils, vol. 1, p. 93-190, pls. 11-20.

________ (1884) On the fossils of the coal-bearing deposits of the Queen Charlotte Islands, Canadian Geol. Survey, Mesozoic Fossils, vol. 1, p. 191-262, pls. 21-33.

________ (1893) Descriptions of two new species of Ammonites from the Cretaceous rocks of the Queen Charlotte Islands, Canadian Record of Science, vol. 5, pp. 441-446, pl. 7.

________ (1900) On some additional or imperfectly understood fossils from the Cretaceous rocks of the Queen Charlotte Islands, with a revised list of the species from those rocks, Canadian Geol. Survey, Mesozoic Fossils, vol. 1, p. 263-307, pls. 33-39.

________ (1903) On some additional fossils from the Vancouver Cretaceous, with a revised list of the species therefrom, Canadian Geol. Survey, Mesozoic Fossils, vol. 1, p. 309-415, pls. 40-51.

Wollemann, A. (1906) Die Bivalven und Gastropoden des norddeutschen Gaults (Aptiens und Albiens), Jahrb. Preuss. Geol. Landesanstalt, Bd. 27, pp. 259-300, pls. 6-10.

Woods, Henry (1899-1913) A monograph of the Cretaceous Lamellibranchia of England, 2 vols., illus. Paleontographical Soc., vols. 53-66.

________ (1912) The evolution of Inoceramus in the Cretaceous period, Quarterly Jour. Geol. Soc. London, vol. 68, p. 1-20, 93 figs., 2 diagrams.