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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 60-5

SUMMARY ACCOUNT OF MESOZOIC AND TERTIARY STRATIGRAPHY, CANADIAN ARCTIC ARCHIPELAGO

E. T. Tozer

Price 50 cents

1960

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Illustrations

SUMMARY ACCOUNT OF MESOZOIC AND TERTIARY STRATIGRAPHY, CANADIAN ARCTIC ARCHIPELAGO[1]

INTRODUCTION AND SOURCE OF INFORMATION

The presence of Mesozoic and Tertiary rocks in the Canadian Arctic Archipelago has been known for many years. Jurassic fossils were the first to be found, by Sir Leopold M'Clintock in 1853, while searching for Sir John Franklin (Haughton, 1857)[2]. Sir Edward Belcher, a contemporary of M'Clintock's, also found some Mesozoic fossils (Belcher, 1855). Per Schei, the industrious geologist of the Second Norwegian Expedition in the "Fram" (1898-1902), collected Triassic invertebrates and Tertiary plants from Ellesmere Island (Schei, 1904; Kittl, 1907). Tertiary deposits with coal had already been discovered by members of the Arctic Expedition led by Sir George Nares (see Feilden and De Rance, 1878). For some 40 years following the "Fram" expedition very little work was done on the Mesozoic and Tertiary rocks, although observations were made by Low (1906), McMillan (1910), Bentham (1936, 1941), and Troelsen (1950, 1952).

Only in the last 10 years has systematic geological work been done on these Mesozoic and Tertiary rocks, and except for valuable collections and useful notes made by Manning (1953, 1956) on Banks Island, most of this work has been done by the Geological Survey of Canada. The work was started after the islands became relatively accessible, following the establishment of weather stations and the increased use of air transport. Geologists of the present generation have consequently worked under much more favourable conditions than their predecessors. Field parties of the Geological Survey have now covered much of the area where Mesozoic and Tertiary rocks are exposed. Some of the results of this work have been published, and several reports are in preparation or awaiting publication. This account summarizes both the published and unpublished data. Published papers treating the Mesozoic and Tertiary rocks include reports by Blackadar (1954), Heywood (1955, 1957), Tozer (1956), Christie (1957), and Thorsteinsson and Tozer (1957, 1959).

In this paper some of the data on Mesozoic and Tertiary rocks was obtained in 1955 on "Operation Franklin" by the following members of the Geological Survey: R.G. Blackadar, Y.O. Fortier, B.F. Glenister, H. Greiner, D.J. McLaren, N.J. McMillan, A.W. Norris, E.F. Roots, J.G. Souther, R. Thorsteinsson, and the writer.

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[1] This report is one of several summary papers prepared by officers of the Geological Survey of Canada and presented at the First International Symposium on Arctic Geology, Calgary, Alberta, 1960. Preliminary publication is by arrangement with the organizing committee of the symposium.

[2] Names and dates in parentheses refer to publications listed in the References.

Results of this field work have been summarized briefly by Fortier (1957), and several preliminary maps of the Mesozoic and Tertiary terrain have been published (GSC Prel. Maps 14-1959, 18-1959, 20-1959, 21-1959, and 36-1959). Several formation names which appear for the first time on these preliminary maps are also used in this paper. They will be fully defined in a Geological Survey report now awaiting publication. This paper also includes unpublished data obtained recently by officers of the Geological Survey as follows: W.L. Davison (Pond Inlet area, 1954); R.L. Christie (northern Ellesmere Island, 1957, 1958); R. Thorsteinsson and the writer (Ellesmere and Axel Heiberg islands, 1956, 1957; western Queen Elizabeth Islands, 1958); R. Thorsteinsson, R.L. Christie, J.G. Fyles, and the writer (Banks and Victoria islands, 1959).

Fossil and age determinations used in this paper have been made by the following: for the Triassic, by the writer; for most of the Jurassic, by H. Frebold; and for some uppermost Jurassic and Cretaceous collections, by J.A. Jeletzky. F.H. McLearn has examined some Cretaceous collections; fossil plants from several levels in the sequence have been identified by Wayne L. Fry and C.D. McGregor, and Mesozoic vertebrate fossils have been identified by Wann Langston of the National Museum of Canada. Some accounts of the Jurassic faunas have already been published (Frebold, 1958a, 1958b) and others by the same author are in press. An account of the Triassic stratigraphy and faunas by the writer is also in press.

DISTRIBUTION AND THICKNESS OF THE MESOZOIC AND TERTIARY ROCKS

The distribution of Mesozoic and Tertiary rocks of the Arctic Islands is shown in Figure 1 and much of the available data on thickness is in Figures 2 and 3. An area of Mesozoic or Tertiary exposures beyond the limits of the map (Fig. 1) is the Cape Dyer - Padloping Island area of southeastern Baffin Island, where McMillan (1910, p. 458) and Kidd (1953) have described "Tertiary type" basalts and non-marine sedimentary rocks with coal seams. This occurrence is remote from the rest of the area under description.

Before considering the character of the various Mesozoic and Tertiary formations, some generalizations on the significance of their relative extent may be drawn from the data on the map (Fig. 1). The thickest and most complete Mesozoic-Tertiary section is preserved in the Sverdrup Basin, an area of pronounced subsidence active from the Middle Pennsylvanian to the early Tertiary, centred approximately on southern Axel Heiberg Island and the Ringnes Islands. The section within this basin is devoid of major unconformities and contains thicker sections than those exposed on the margins of the basin (Fig. 2). Formations that extend throughout the area—for example the Isachsen—are approximately 10 times thicker on the axis of the basin than on the margins. The position of the area of greatest sedimentation, as in many basins, evidently changed with the passage of time. Determination of the position of the thickest accumulation of sediments for each time interval is still not possible, owing to the incompleteness of the data.

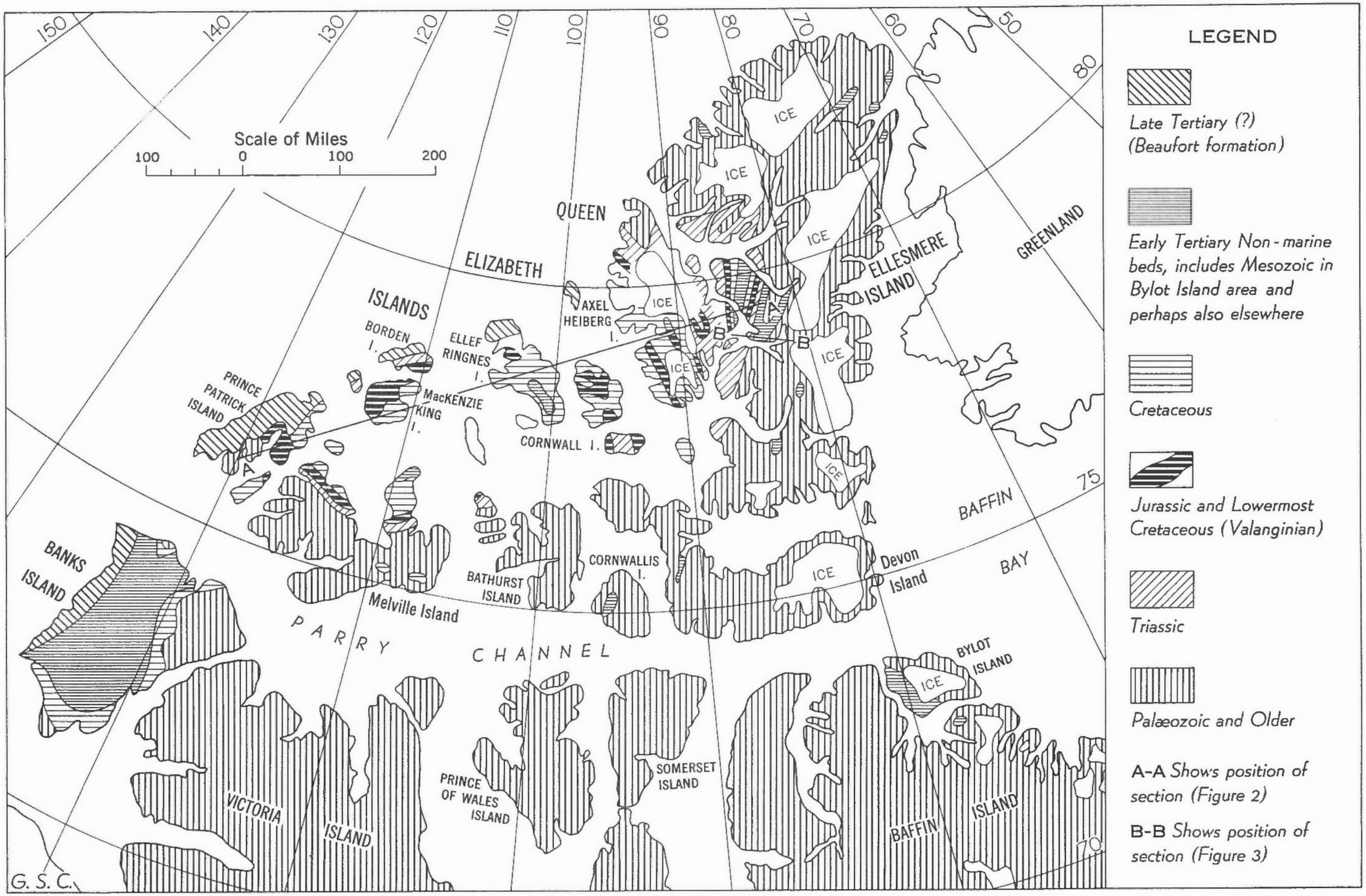

Figure 1. Sketch map showing distribution of Mesozoic and Tertiary rocks in the Canadian Arctic Archipelago

However it would appear that in Lower Cretaceous time western Axel Heiberg Island received the greatest thickness of sediment; in Triassic time the thickest sections seem to have been formed farther east, on eastern Axel Heiberg Island (Fig. 2).

In the western part of the area several formations are transgressive and the sections are incomplete compared with those nearer the axis of the basin. The following is a summary of transgressive formations.

(1) The Schei Point formation is transgressive near Salmon Point, Prince Patrick Island, where it rests on Devonian rocks, having overstepped the Bjorne formation. This outcrop is too small to show on Figure 1, but it is shown on the geological map of the western Queen Elizabeth Islands (Thorsteinsson and Tozer, 1959).

(2) Unnamed Sinemurian beds on Borden Island are transgressive for they rest on the Schei Point formation, having overstepped the Heiberg beds (Thorsteinsson and Tozer, 1959).

(3) Basal Wilkie Point beds (Toarcian) are transgressive near Mould Bay, Prince Patrick Island, where they rest on the Devonian, having overstepped all the older Mesozoic beds (Tozer, 1956).

(4) The Mould Bay formation (uppermost Jurassic - Valanginian) rests directly upon Devonian rocks between Walker Inlet and Mould Bay, Prince Patrick Island, having overstepped the Wilkie Point beds exposed a few miles to the east (Tozer, 1956).

(5) Lower Cretaceous beds (Isachsen and Christopher formations) appear to be transgressive over a wide area. This relationship prevails on southern Melville Island[1], and on Banks Island. On Melville Island and northern Banks Island these beds rest on Devonian rocks; on southern Banks Island, near Nelson Head, they rest on the Precambrian.

Formations of approximately, and perhaps exactly the same age are transgressive on the west side of the sedimentary basin of the Western Interior of Canada.

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[1]The beds in question were tentatively mapped as "Eureka Sound" (i.e. probably Tertiary) by Thorsteinsson and Tozer (1959), but plant microfossils from the basal beds are upper Jurassic or Lower Cretaceous according to C.D. McGregor and fossil bones from the upper beds have been identified by Wann Langston as remains of plesiosaurs. These beds are therefore Mesozoic, and from their lithology, Thorsteinsson and the writer now assign them to the Isachsen and Christopher formations.

In the eastern and southeastern parts of the area shown by Figure 1, the Eureka Sound formation (Upper Cretaceous(?) and Tertiary) transgresses from the Sverdrup Basin and rests disconformably upon various older formations (Fig. 3). This transgression evidently affected a very extensive area, because outliers of Eureka Sound beds are known on northern, northeastern and eastern Ellesmere Islands (Feilden and De Rance, 1878; Schei, 1904; Troelsen, 1950; Bentham, 1941; and Christie, 1957, and personal communication). Such outliers are also known on Devon Island (GSC Map 20-1959), and Cornwallis Island[1]. Non-marine beds with coal overlie Precambrian rocks on Bylot Island and near Pond Inlet, northern Baffin Island (Low, 1906, pp. 228-229; W.L. Davison, personal communication). Lithologically these beds represent the same facies as the Eureka Sound formation. However, according to C.D. McGregor, plant fossils from the Pond Inlet beds are probably Jurassic or Lower Cretaceous, so these beds appear to be older than the lithologically similar transgressive deposits to the north.

MESOZOIC AND TERTIARY LITHOFACIES

There are few different lithofacies of the Mesozoic and Tertiary formations and some facies recur at several levels in the section. All Mesozoic and Tertiary formations appear to have been deposited in shallow water, some below strand line, others above. The sedimentary environment probably resembled that in which the contemporary formations were laid down in the Western Interior of continental North America.

The lithofacies may be described under four main headings: (1) marine facies; (2) non-marine facies; (3) conglomerate (fanglomerate?) facies; (4) volcanic facies.

MARINE FACIES

The marine lithofacies may, in turn, be further subdivided as: (a) shale-siltstone facies; (b) calcareous siltstone-sandstone facies; (c) sand-sandstone facies.

Shale-siltstone Facies

The dominant rock is thin-bedded, grey to black shale. Calcareous and pyritic concretions are common and thin beds of silty and argillaceous limestone also occur. Siltstone may be interbedded, and in one formation (Blind Fiord) siltstone is dominant. Formations of this facies are: Blind Fiord and Blaa Mountain (Triassic); Savik

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[1]In 1958, R. Thorsteinsson (personal communication) revisited the type section of the Intrepid Bay formation and collected plant microfossils which have been dated as Tertiary by C.D. McGregor. The exposures of the "Intrepid Bay formation" at Rookery Creek, northern Cornwallis Island are now dated as Devonian (Thorsteinsson, 1958, p. 111, and personal communication).

(Jurassic); Deer Bay (uppermost Jurassic and lowermost Cretaceous); Christopher (Lower Cretaceous); and Kanguk (Upper Cretaceous). This facies characterizes, in particular, the marine deposits of the axial part of the Sverdrup Basin. Many of these shales and siltstones (Blind Fiord, Blaa Mountain, Savik, and Deer Bay) pass laterally into arenaceous deposits on the margins of the Sverdrup Basin (Figs. 4, 5, 6). The Christopher and Kanguk formations, on the other hand, extend, essentially as shale, throughout the entire area where rocks of their age have been found. These two formations, unlike the underlying marine shales, are not known to pass laterally into arenaceous equivalents.

Calcareous Siltstone-sandstone Facies

This facies occurs only in the Triassic. The rock is commonly grey, brown-weathering, calcareous quartz-siltstone, or fine-grained calcareous sandstone. Minor grey bioclastic limestone is interbedded in some sections. This facies is characteristic of the middle part of the Triassic sequence (Anisian to Karnian) on the east, south, and west margins of the Sverdrup Basin (Fig. 4), where it has been named the Schei Point formation. Tongues of typical Schei Point rock interfinger with the contemporary Blaa Mountain shales on western Ellesmere Island (Raanes Peninsula, Fosheim Peninsula, and on the shores of Nansen Sound). There are also thin shales of Blaa Mountain facies in some Schei Point sections. This calcareous facies resembles that of the "Grey beds" (Middle and Upper Triassic) of northeastern British Columbia (McLearn and Kindle, 1950, p. 46).

Sand-sandstone Facies

Formations of this facies consist mainly of fine- to medium-grained quartz sand, poorly to completely unconsolidated. Concretions and thin beds of cemented rock also occur. The cement is commonly calcareous or ferruginous and these hard beds are usually dusky red or brown. In the Jurassic, grey phosphatic nodules and glauconitic beds are also common. This facies is well developed on the margins of the Sverdrup Basin (see Figs. 5 and 6). Jurassic formations of this facies are the Lower Wilkie Point and Jaeger. The Mould Bay formation (Upper Jurassic and lowermost Cretaceous) is the younger representative. Both formations pass into shale equivalents towards the axis of the basin. Thin beds of this facies also occur in the Heiberg (Triassic), Awingak (Jurassic), and Isachsen (Lower Cretaceous) formations, but the greater part of these formations is non-marine.

NON-MARINE FACIES

The non-marine beds of the Archipelago are particularly uniform in gross aspect, irrespective of age. They consist of interbedded sand, siltstone, shale and coal. The sand and sandstones are light-coloured, essentially quartzose rocks, uncemented, or cemented by carbonate, and, less commonly ferruginous material. Shales and siltstones are dark coloured, fissile and micaceous. All these rocks are commonly carbonaceous. Crossbedding is very prevalent. This facies occurs in the Upper Triassic (Heiberg), Upper Jurassic (Upper Wilkie Point and Awingak), Lower Cretaceous (Isachsen), mid-Cretaceous (Hassel), and the Tertiary (Eureka Sound). The greater part of these formations are purely of the facies as described above; however, as noted above, the Heiberg, Awingak, and Isachsen formations contain thin marine beds (making up a very small percentage of the total thickness) in some sections. The presence of these thin beds suggests that most (and perhaps all) of these formations were deposited fairly close to the strand line. The Isachsen formation is characterized by remarkable quartz grits and conglomerates and preserves this distinctive character over a very extensive area.

Under this heading we may also include the Bjorne formation, of Lower Triassic age. This formation is a red-weathering quartz sand and sandstone, with, in some areas, interbeds of conglomerate. Poorly preserved marine shells occur in thin beds in a few sections, but most of the formation is completely non-fossiliferous and was probably deposited above strand line. The Bjorne sands differ from those of the Heiberg and later non-marine formations as they lack carbonaceous material. This probably reflects lack of carbonaceous material in the source area, rather than a radically different environment of deposition.

CONGLOMERATE (FANGLOMERATE?) FACIES

Conglomerate is not common in the Mesozoic and Tertiary section of the Archipelago. As noted above, some beds do occur in the Bjorne and Isachsen formations, but they are mainly composed of small pebbles. In addition, there are some conglomerates with large boulders (up to 1 foot in diameter) that deserve special mention. On eastern Axel Heiberg Island, conglomerates, composed mainly of gabbro pebbles and cobbles, overlie, apparently conformably, typical, fine-grained, non-marine beds of the Eureka Sound formation. These conglomerates lie at the foot of the prominent range, composed mainly of Triassic shales with gabbro sills, that extends from Stolz Peninsula to Buchanan Lake. It seems probable that these conglomerates were derived from the nearby range. They may therefore represent fanglomerates and their possible tectonic significance is discussed below. Lithologically similar conglomerate also occurs south of Li Fiord, on the west side of Axel Heiberg Island, but it is of uncertain age, perhaps Lower Cretaceous (Fortier, 1957, p. 435). Small amounts of conglomerate were noted in the Eureka Sound beds of Ellef Ringnes Island, by H. Greiner (see Fortier, 1957, p. 436; GSC Map 14-1959).

VOLCANIC FACIES

Some volcanic rocks occur in the Mesozoic sequence. The most notable are the Strand Fiord basalts, known on west-central Axel Heiberg Island (Fig. 2) (Fortier 1957, p. 436; GSC Map 36-1959). J.G. Souther has also described volcanic breccia in the Isachsen formation of the Strand Fiord area. Seams of yellow, greasy clay, probably bentonite, occur in the Christopher and Kanguk formations. As already mentioned, McMillan (1910) and Kidd (1953) have described basalts, apparently of subaqueous origin, in southeastern Baffin Island. These basalts occur in an area remote from the Sverdrup Basin and it has been suggested that they are the same age as the Tertiary basalts of the Disco Bay area, on the Greenland side of Baffin Bay.

SEQUENCE OF FORMATIONS AND FAUNAS

The sequence of Mesozoic and Tertiary formations in the Canadian Arctic Archipelago is summarized in tabular form on the Correlation Chart (in pocket). The conventional patterns used on this chart follow those used on the charts published by the Geological Society of America. Oblique lines represent lack of knowledge, mainly from absence of exposures. Vertical lines represent gaps in the sequence, proven or hypothetical. Like most correlation charts this compilation is subject to revision and amplification, and the position of many boundaries with respect to the time scale may be changed. However the sequence of formations in each column may be accepted as moderately well established. The remarks that follow provide brief documentation for the age assignments adopted and also qualify some of the correlations which are not as well established as might appear from an examination of the chart alone.

TRIASSIC

The writer has identified the Triassic invertebrates listed below and assumes responsibility for the age assignments. A brief abstract on the Triassic faunas has already been published (Tozer, 1958) and a description of the stratigraphy and leading faunas is now in press (GSC Mem. 316).

Lower Triassic (Scythian) faunas occur in the Blind Fiord formation of northern Ellesmere and Axel Heiberg islands. They range in age from lowest Scythian (with Otoceras) to highest Scythian (with Olenikites), and several faunas of intermediate age also occur (e.g. a fauna with Arctoceras, Meekoceras, Euflemingites etc.. and another with Wasatchites). The Bjorne formation, also dated as Scythian, has not provided diagnostic fossils but there is good evidence, from stratigraphic position and interfingering relationships, that the Bjorne and Blind Fiord formations are contemporary, the Bjorne being the relatively coarse-grained, possibly non-marine equivalent of the marine Blind Fiord siltstone and shale.

In the Middle Triassic, faunules of Anisian age (with Ptychites, Frechites and Parapopanoceras) are known. They occur near the base of the Blaa Mountain formation (of the Sverdrup Basin) and in the Schei Point beds of the east and southeast margins of the basin. The Nathorstites fauna, which is evidently Ladinian (late Middle Triassic) occurs in the Blaa Mountain beds of Nansen Sound and Blind Fiord and in the Schei Point beds of Bay Fiord, Bjorne Peninsula and Table Island. Anisian and Ladinian faunas are unknown in the Schei Point formation of Cameron, Prince Patrick and Borden islands. On Cameron and Prince Patrick islands the paucity of beds beneath the Upper Triassic (Karnian) part of the Schei Point suggests that Anisian and Ladinian beds are unrepresented, not merely unknown.

Faunas of Karnian (Upper Triassic) age, with Halobia, Sirenites, Jovites etc. are widely found, in both the Schei Point and Blaa Mountain formations.

The Heiberg formation, which follows the Schei Point and Blaa Mountain beds, is mainly non-marine, but in the lower half, two thin marine bands occur, with faunules composed mainly of pelecypods. The lower marine band contains Meleagrinella and Oxytoma and is Upper Karnian or early Norian. On the correlation chart the base of the Heiberg is arbitrarily aligned with the Karnian-Norian boundary, but it should be noted that this exact correlation has not been established, and is not even suggested. The upper marine band of the Heiberg contains the cosmopolitan Norian species, Monotis ochotica (Keyserling), so the age of this bed is clear. Above the Monotis bed there are more non-marine strata with coal seams and fossil plants. These plants have been examined by W.L. Fry (personal communication), who states that the few forms known in the Heiberg resemble species from the "Rhaeto-Liassic" flora of East Greenland which occurs in beds (Kap Stewart formation) that are said to bridge the Triassic-Jurassic boundary. Fry states that the Heiberg plants are too few in number to make an accurate age determination at present and it is not possible to say if lowermost Jurassic beds are represented in the Heiberg, as they are in the Kap Stewart formation. However the Heiberg beds are certainly not younger than Toarcian, and the formation also appears to be pre-Sinemurian.

JURASSIC

Much of the Jurassic time is represented by deposits in the Archipelago. In general the history may be summarized thus: marine conditions prevailed at intervals from the Sinemurian to the Callovian; then followed mainly non-marine sediments throughout most of the area; and towards the end of the Jurassic, widespread marine conditions again returned. Following the last main Jurassic transgression, marine conditions apparently continued into the Cretaceous, because the Deer Bay and Mould Bay formations, both apparently homogeneous rock units, contain uppermost Jurassic and lowermost Cretaceous marine faunas. During the periods of widespread marine conditions, distinct facies belts can be recognized (see Figs. 2, 5, 6).

The Jurassic ammonoids and most of the pelecypods have been identified by Frebold, but the species of Buchia from the Portlandian (sensu lato) have been determined by Jeletzky. Frebold and Jeletzky are therefore responsible for all the fossil and age determinations that follow. Some of this faunal data has been published, and wherever relevant, reference is given to the papers (e.g. Frebold 1958a, 1958b). Where no such reference is given, the information has been received orally or is in a manuscript.

The oldest known marine Jurassic rocks contain poorly preserved arietitids and are dated as Sinemurian by Frebold (1958b, p. 31, and GSC Bull. 59 in press). These fossils have been collected only on Borden Island and northwestern Melville Island. The Borden Island specimen was not collected in situ, but there is little doubt that it came from the beds designated "Map-unit 15" by Thorsteinsson and Tozer (1959). "Map-unit 15" on Borden Island is a discrete deposit, with sharp upper and lower boundaries, presumably laid down during a relatively short period of marine transgression. On Melville Island the Sinemurian beds are not readily separated from the overlying Wilkie Point beds. However the writer believes, from the apparent absence of Pliensbachian deposits in the Archipelago, that on both Borden and Melville islands the Sinemurian beds are probably separated from the overlying strata by a stratigraphic diastem.

Toarcian beds (with Dactylioceras and Catacoeloceras) are widely represented. In the marginal, sandy facies, Toarcian faunas occur in the basal beds of the Wilkie Point formation of Prince Patrick Island (Tozer, 1956; Frebold, 1958a); the Jaeger formation of Cornwall Island, where they were collected by H. Greiner (Frebold, in press), and unnamed beds on Fosheim Peninsula, Ellesmere Island (Frebold, 1958b, p. 32). In the shale facies they occur in the Savik formation of western Axel Heiberg Island (Frebold, 1958a, p. 3; 1958b, p. 32). Toarcian also occurs in the lower, shaly part of the Wilkie Point formation of Borden Island (Thorsteinsson and Tozer, 1959; Frebold, 1958b, p. 31). In this last area the marine shale and sand facies interfinger and the Toarcian beds of Borden Island, although shale, are arbitrarily placed in the Wilkie Point formation. Toarcian fossils have not yet been found on Melville Island.

Lower Bajocian beds, with Leioceras opalinum (Reinecke), Pseudolioceras m'clintocki (Haughton), and Oxytoma jacksoni (Pompeckj) are also widespread (Frebold, 1958a, p. 23; 1958b, p. 31; and in press). They are known in the sand facies of Prince Patrick, Melville, and Mackenzie King islands (Wilkie Point formation); also on Cameron and Cornwall islands (Jaeger formation). In the shale facies (Savik formation), Oxytoma jacksoni occurs on western Axel Heiberg Island. This species, which seems to be a reliable Lower Bajocian index fossil (Frebold, in press) has recently been collected in shale on northern Ellef Ringnes Island by D. Stonge of the Geographical Branch. Full details of this last occurrence are not yet available.

Following the Lower Bajocian it becomes more difficult to generalize regarding the sequence of Jurassic beds and faunas in the Archipelago. Several faunas are known, but most are known only from one or two localities and complete sequences are unknown in any one area.

Three Middle Jurassic[1] faunas occur on Prince Patrick Island (Frebold, 1958a, 1958b), characterized by Arkelloceras, Cranocephalites vulgaris Spath and Arcticoceras ishmae (Keyserling). Arcticoceras occurs above Arkelloceras, but Cranocephalites occurs in a different section. Callomon (1959) places Cranocephalites vulgaris in the Lower Bathonian and Arcticoceras ishmae in the Upper Bathonian. In a paper awaiting publication, Frebold

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[1]Following Arkell (1956), the Callovian is now placed in the Middle Jurassic.

places the Arkelloceras beds close to the Bajocian-Bathonian boundary. Arkelloceras is now also known from Melville Island. On Prince Patrick and Melville islands the beds with these faunas are followed by non-marine strata (Upper Wilkie Point).

Callovian beds, with Cadoceras, are known on Cornwall Island in the sand facies (Jaeger formation) and on western Axel Heiberg Island in shale (Savik) (Frebold, 1958b, p. 32).

Non-marine beds within the Jurassic section have already been mentioned. On Prince Patrick and Melville islands these beds are known as the "Upper Wilkie Point formation". Somewhat similar, and partly contemporary beds on Cornwall and Axel Heiberg islands are placed in the Awingak formation. The Awingak beds are typically exposed at Buchanan Lake, Axel Heiberg Island, where they were first studied by J.G. Souther, and later, briefly, by the writer (see GSC Prel. Map 36-1959). These beds are mainly non-marine, but Souther collected marine fossils from several beds. Among these, Frebold has determined a faunule of Lower Kimmeridgian or Oxfordian age (with Amoeboceras sensu lato and Buchia). At this point, it must be mentioned that Souther also collected ammonoids identified by Frebold as Cardioceras (Scarburgiceras) aff. mirum Arkell, of Lower Oxfordian age (Frebold, 1958b, p. 32). Souther believed that these specimens were obtained from the Savik shale, below the mainly non-marine Awingak. Unfortunately it has not been possible to confirm this interesting—and for the Arctic Island, unique—occurrence. The matrix attached to the cardioceratid is a hard, ferruginous sandstone, of a type common in the Awingak, but which the writer could not find in the Savik. The writer therefore believes that the specimens of Cardioceras may, in fact, be from the Awingak. However it should also be stressed that this interpretation has not been confirmed. Poorly preserved specimens of Buchia have been obtained from the Awingak equivalent of Fosheim Peninsula, Ellesmere Island, but here, as at Buchanan Lake, most of the section is non-marine. On western Axel Heiberg Island, and on Cornwall Island no marine bands are known in the Awingak. In these areas the beds appear to be entirely non-marine.

On Mackenzie King Island non-marine Jurassic beds have not been found. Although exposures are far from perfect, it appears that the Mould Bay formation rests directly upon Lower Wilkie Point beds, of Bajocian age. It may be that the sheet (or wedge) of non-marine Jurassic sediment did not reach this area; alternatively it is possible that such beds were deposited, and then removed. There is a third possibility, discussed below, namely that equivalents of these non-marine strata occur in the basal part of the Mould Bay formation.

UPPERMOST JURASSIC AND LOWERMOST CRETACEOUS

Towards the end of the Jurassic, marine conditions returned to the Sverdrup Basin and its southwestern margin. These conditions prevailed from the Jurassic through to the Valanginian and led to the deposition of the Mould Bay sands and the Deer Bay shale. Pelecypods, including Buchia, are common and widely distributed; ammonoids occur in abundance at some localities but are rare compared with the pelecypods. Most of the fossils from the Mould Bay and Deer Bay formations have been identified by Jeletzky, and some of the ammonoids have been determined by Frebold.

In most sections of the Deer Bay shale (e.g. Fosheim Peninsula, Ellesmere Island; eastern Axel Heiberg Island), and of the Mould Bay sands (Prince Patrick Island), the oldest fossils known are of Portlandian age, in the broad sense. These Portlandian faunules include those with Buchia fischeri (d'Orbigny) (identified and dated by Jeletzky), and Dorsoplanites sp. indet. (Frebold, 1958b, p. 32). According to Jeletzky, several faunules of Berriasian and Valanginian age also occur in the Mould Bay and Deer Bay formations.

The section of these beds on Mackenzie King Island is unusual and deserves special mention. In this section the sand and shale facies interfinger. Arbitrarily the beds have been placed in the Mould Bay formation (Thorsteinsson and Tozer, 1959), but there are at least three distinct members; a lower shale, a middle sand, and an upper shale (Fig. 2). The lower shale contains fossils (identified by Frebold) as Amoeboceras sp., of late Oxfordian or early Kimmeridgian age, followed closely by Buchia cf. fischeri (d'Orbigny) (identified by Jeletzky) of Upper Portlandian age. No fossils as old as the Amoeboceras have yet been found in the Deer Bay or Mould Bay formations of other localities. As already mentioned, representatives of the Awingak (non-marine Upper Jurassic) formation appear to be absent on Mackenzie King Island. The occurrence of Oxfordian or Kimmerdgian fossils in the basal Mould Bay may indicate that time-equivalents of the Awingak occur in this basal shale, i.e. that the third possibility mentioned above is applicable. This will be a difficult problem to resolve because it involves correlation between marine and mainly non-marine beds.

CRETACEOUS

The widespread transgression that left the Mould Bay and Deer Bay formations was followed by an interval when the surface of sedimentation again rose above strand line. This is testified by the Isachsen formation which is almost entirely non-marine, although on western Axel Heiberg and Ellef Ringnes islands, Valanginian species of Buchia have been identified by Jeletzky from thin beds near the base (e.g. Heywood, 1957, p. 11). The Isachsen formation, with its distinctive coarse-grained quartz grits and conglomerates is remarkably uniform from Fosheim Peninsula, Ellesmere Island to the southern tip of Banks Island, a distance of 800 miles. On Banks and southern Melville islands the Isachsen beds rest directly upon Devonian or Precambrian rocks; elsewhere they overlie the Deer Bay or Mould Bay formations. Marine faunas of Hauterivian and Barremian age are unknown in the Archipelago and it is probable that much of the Isachsen represents this interval. The few fossil plants obtained so far do not permit a precise age determination.

The Isachsen formation is followed by the Christopher marine shale. The Christopher, unlike the underlying marine Mesozoic formations, does not pass laterally into a marginal sand facies, although the sections on Melville Island contain more silt and sand than those of the Ringnes Islands and Axel Heiberg Island. Diagnostic fossils are rare in the Christopher, and those that have been obtained are from the upper beds. Beudanticeras, Lemuroceras and other Lower Albian fossils are known from the upper beds of the Christopher of Fosheim Peninsula on Ellesmere Island, western Axel Heiberg Island, Ellef Ringnes Island, Sabine Peninsula on Melville Island, and at several localities on Banks Island. Some poorly preserved fossils from the lower Christopher beds of Mackenzie King Island have been identified by Jeletzky as *Inoceramus* cf. *labiatiformis* Stolley, and "the fragment of the living chamber of an uncoiled ammonite strongly resembling the living chamber of *Tropaeum*...". Jeletzky (1960) has recently found *Tropaeum*, of Aptian age, in the northern Richardson Mountains. His tentative identification, coupled with the presence of a considerable thickness of marine beds beneath the fossiliferous Albian horizons, suggests that the lower Christopher beds may be of Aptian age. This is admittedly inconclusive, but on the correlation chart the lower Christopher beds are tentatively placed in the Aptian.

The Christopher shales are followed by yet another non-marine unit, the Hassel formation, in which diagnostic fossils are unknown. In the Strand Fiord area, western Axel Heiberg Island, the Hassel formation is overlain by basalt flows. These are the only definitely-dated Mesozoic volcanic rocks in the Archipelago.

The last marine Mesozoic transgression occurred in the Upper Cretaceous and left the Kanguk formation. The upper Kanguk shales, on Fosheim Peninsula, Axel Heiberg Island and Ellef Ringnes Island contain *Inoceramus* species of the *lobatus* group (identified by McLearn and Jeletzky). On Graham Island (see Prel. Map 21-1959), H. Greiner collected specimens identified by McLearn as *Inoceramus* cf. *pictus* Sowerby, of Cenomanian or Turonian age. It is tentatively suggested that the shale on Graham Island is the time-equivalent of the lower, non-fossiliferous part of the Kanguk elsewhere, but this is not yet proven.

The *Inoceramus lobatus* fauna of the Kanguk formation permits a correlation with the fauna of the Patoot beds of Disco Bay, West Greenland, described by Ravn (1918). Teichert (1939, p. 155) indicated that the affinities of the Patoot fauna are with assemblages from the Western Interior of continental North America and suggested a direct marine link between the Canadian Arctic Islands and West Greenland. Teichert, with considerable ingenuity, proposed this connection before any Upper Cretaceous beds were known from the Canadian Archipelago. The Kanguk transgression may have extended across Ellesmere Island, towards Baffin Bay and Disco Island, as suggested by Teichert. If so, the deposits were removed before the deposition of the Eureka Sound formation. The writer is disinclined to accept Teichert's hypothesis and believes that a land area probably occupied the migration route he proposed. It seems necessary to invoke this land to provide a source for the Upper Cretaceous and Tertiary beds that filled the Sverdrup Basin.

TERTIARY

Within the Sverdrup Basin the Kanguk formation is followed by up to 10,000 feet of coal measures—the Eureka Sound formation. The Eureka Sound formation, as already noted, is not confined to this basin, for outliers resting on Palaeozoic rocks occur on eastern Ellesmere, Devon and Cornwallis islands.

Study and correlation of these non-marine outliers is not easy because the only fossils available are plants, and they have not yet been studied in detail. However studies made by W.L. Fry and C.D. McGregor suggest that most collections, both from the Sverdrup Basin and the outliers, are of early Tertiary (Paleocene or Eocene) age. Some, however, may be upper Cretaceous. The study of these outliers is also complicated by the fact that some may be even older, for, according to McGregor the microfossils from Pond Inlet (northwestern Baffin Island) are probably Jurassic or Cretaceous.

Following the opinion of Schei (1904) and Troelsen (1950, 1952), it was originally supposed that the Eureka Sound formation was deposited after the folding of the Mesozoic rocks of Ellesmere and Axel Heiberg islands. Recent work (Thorsteinsson and Tozer, 1957) has shown that the Eureka Sound beds are folded and are essentially pre-orogenic, and that the age of the orogeny is Tertiary. However, it should be mentioned that on eastern Axel Heiberg Island there are conglomerates composed mainly of gabbro pebbles that may have a bearing on this question. Immediately north of the head of Mokka Fiord these conglomerates are steeply tilted and overlie, conformably, typical Eureka Sound coal measures. Conglomerates do not occur in the lower, typical, Eureka Sound beds, wherever the writer has seen them. The conglomerates were probably derived from the gabbro sills that intrude much of the Mesozoic section, and which occur in the Triassic beds exposed along a north-trending belt immediately west of the conglomerate at Mokka Fiord. The boundary between the conglomerate and the Triassic rocks with gabbro sills is faulted. The conglomerate contains large boulders, probably derived from the nearby sills, and as already mentioned, may be a fanglomerate. Probably this fanglomerate(?) formed along the fault-line scarp during an early stage of the fault movement. The conglomerate therefore seems to be synorogenic rather than pre-orogenic, and its appearance probably signals the start of the Tertiary earth-movements that terminated the long, essentially uninterrupted period of sedimentation within the Sverdrup Basin.

At present there are no beds known in the eastern part of the Arctic Islands that post-date the Tertiary orogeny. However on the western edge of the Archipelago, from Banks Island to Meighen Island, a remarkable sheet of unconsolidated sediment occurs. This has been named the Beaufort formation (Tozer, 1956) and it consists of crossbedded sand and gravel, at least 250 feet thick, laden with logs and sticks of non-petrified wood in a remarkably fresh state of preservation. This wood seems to be too old for a radiocarbon age-determination. Although the Beaufort, from its lack of consolidation and from the fresh nature of the wood, might seem to be very young, other features suggest that it may be as old as Tertiary. There is no clear evidence that the Beaufort formation is underlain by glacial deposits. On Prince Patrick Island there is evidence to suggest that some glacial events followed the deposition of the Beaufort (Tozer, 1956). J.G. Fyles (personal communication), from the evidence on Banks Island, is satisfied that Pleistocene deposits overlie the Beaufort formation in that area. On Banks Island the Beaufort formation rests disconformably upon coal measures which are probably approximately (or exactly) correlative with the Eureka Sound formation, so the Beaufort is presumably younger than early Tertiary. The continuity of the Beaufort terrain across M'Clure Strait and the channels separating the northwestern islands of the Archipelago suggests that it was laid down before much, and perhaps all of the Archipelago became separated from the mainland.

The absence of datable late Tertiary rocks in the Archipelago means that there is very little evidence available from which to draw conclusions regarding the late Tertiary history. Presumably the time interval following deposition of the Eureka Sound formation was a period of erosion for most of the Archipelago. The sounds and straits that divide up the islands to form the Archipelago of today presumably represent the drowned valley of the rivers (Fortier and Morley, 1956, Fig. 3) that carried the products of this erosion towards the continental shelf of the north and northwest, and to Baffin Bay. Perhaps the Beaufort formation was deposited during this essentially erosional interval, and represents the edge of the belt of late Tertiary deposits that presumably lie on the Continental Shelf.

PALAEOGEOGRAPHY

It has already been shown (see Figs. 2 and 3) that the Sverdrup Basin contains a very thick mass of clastic Mesozoic and Tertiary sediment. The distribution of Mesozoic facies belts (see Figs. 4, 5, 6) suggest that most, or all of this sediment was derived from the east and south. Most of the present-day surface of the western Parry Islands and northeastern Banks Island is made of Devonian sandstone, and the Devonian formations of this area are very thick. This belt of Devonian clastic rocks extends today, more or less continuously, from Banks Island to southern Ellesmere Island. In Mesozoic and early Tertiary times these Devonian clastics may have extended farther south to form a very extensive terrain. Such a terrain may have been the source area for much of the sediment that filled the Sverdrup Basin. Erosion of the Precambrian Shield may also have contributed to this mass of sediment. In particular, the Isachsen formation, much of which may represent a first-cycle orthoquartzite, may have been derived from the breakdown of Shield rocks.

Most palaeogeographers (e.g. Haug, 1910, p. 1113; Diener, 1916; Frebold, 1929, pls. IV-VII; Stille, 1948; Arkell, 1956, p. 604) consider that in Mesozoic time the Arctic Ocean had essentially the same extent as today. The marine Mesozoic deposits of the Canadian Arctic Archipelago were presumably deposited during short-lived transgressions from the "Primordial Arctic Ocean" to the north. Some idea of the positions of the Triassic, Jurassic and Lowermost Cretaceous shorelines may be obtained from an examination of the maps showing the facies belts (Figs. 4, 5, 6), from which it would appear that the shorelines were not far from the present eastern and southern limits of outcrop. For the later Cretaceous marine deposits (Christopher and Kanguk formations) we have less data. The occurrence of outliers of Christopher formation on southern Melville Island may indicate that this transgression was particularly extensive.

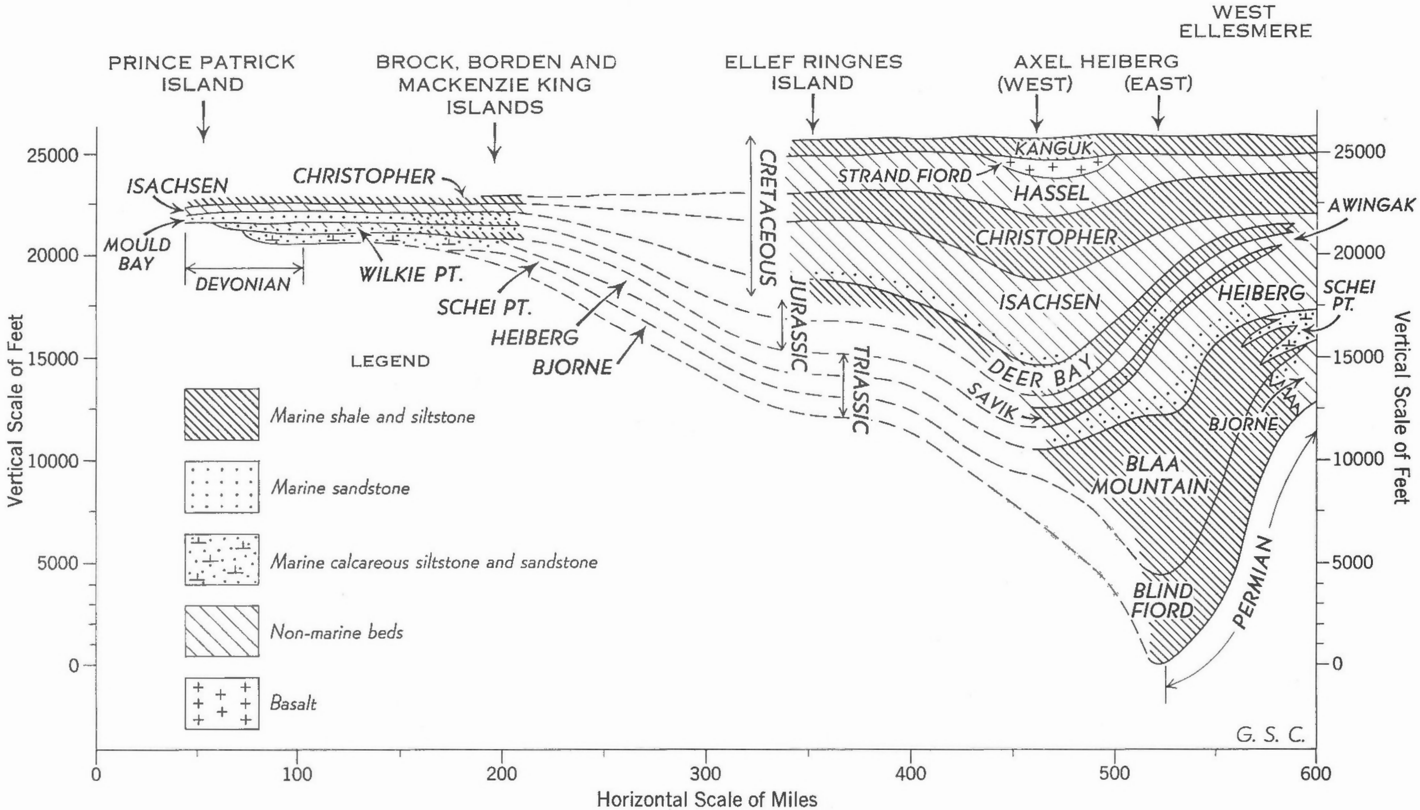

Figure 2. Diagrammatic section from Fosheim Peninsula, West Ellesmere Island to Prince Patrick Island, showing approximate thickness and gross lithology of the Mesozoic formations. Position of section is shown on Figure 1. This section is an interpretation of the relationship prior to the Tertiary orogeny (the parts of the section shown by dashed lines are not exposed). In the eastern part of the section, from Ellef Ringnes Island to West Ellesmere Island, up to 10,000 feet of non-marine beds (Eureka Sound formation) overlie the Kanguk shale. The thin Sinemurian beds of Borden Island are not shown.

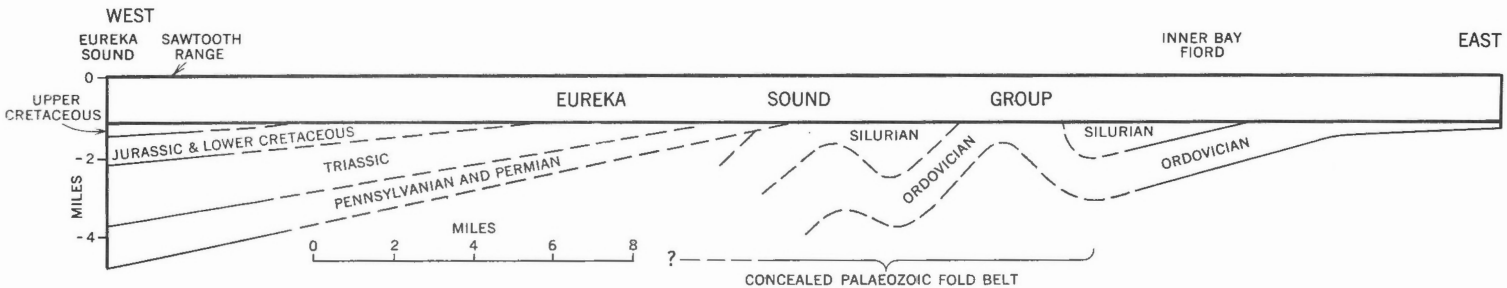

Figure 3. Diagrammatic section across west central Ellesmere Island, at the latitude of Bay Fiord, showing the supposed relationship of the Eureka Sound formation to older beds. Position of the section is shown on figure 1. This section shows the relationship before the Tertiary orogeny (From Thorsteinsson and Tozer, 1957)

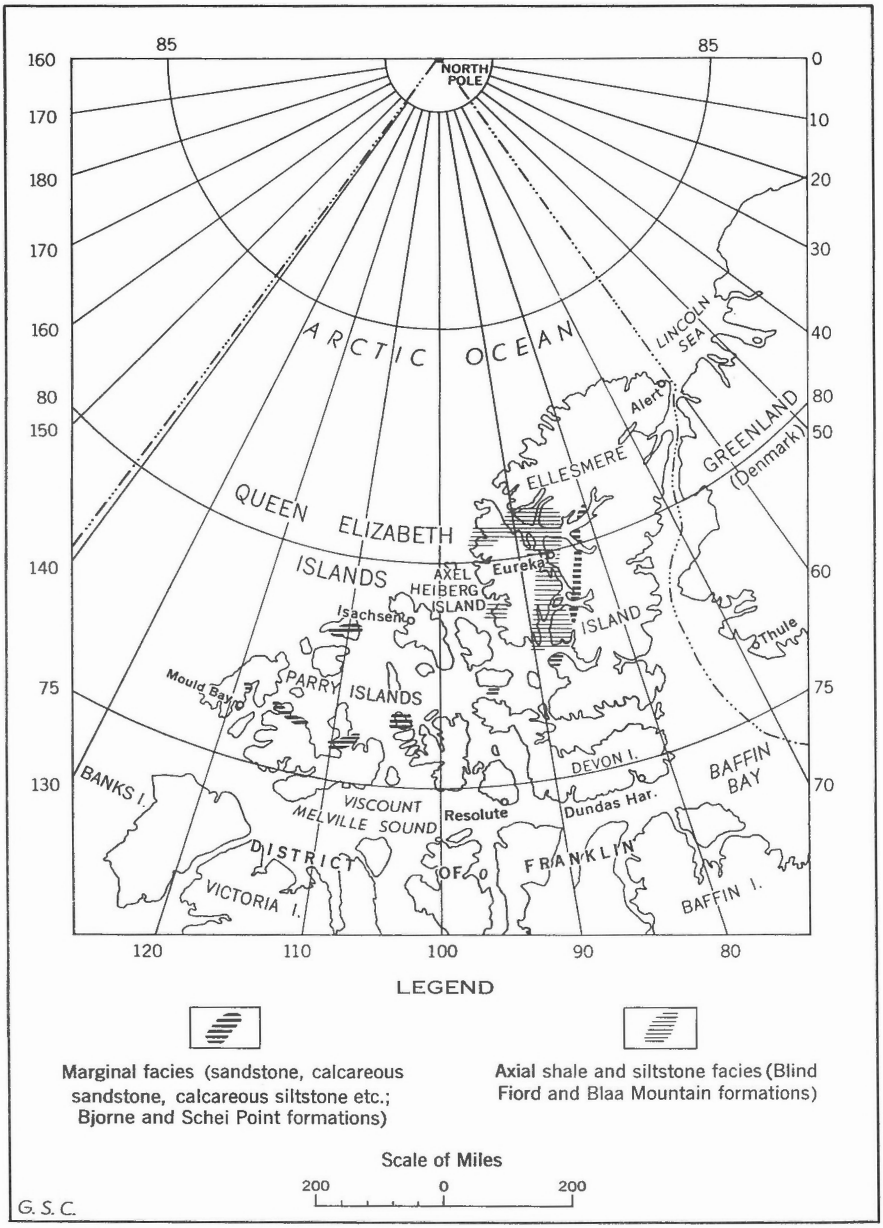

Figure 4. Triassic facies belts

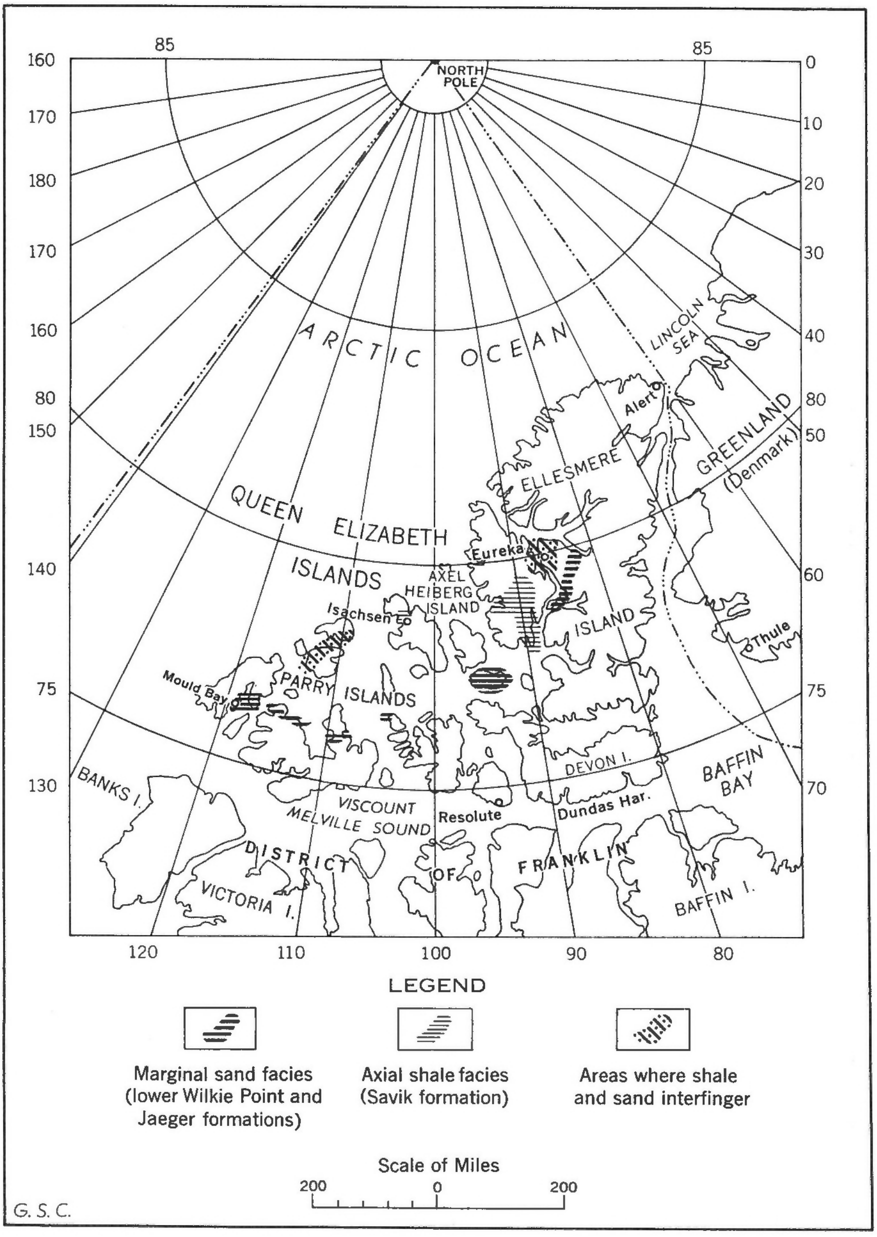

Figure 5. Jurassic facies belts

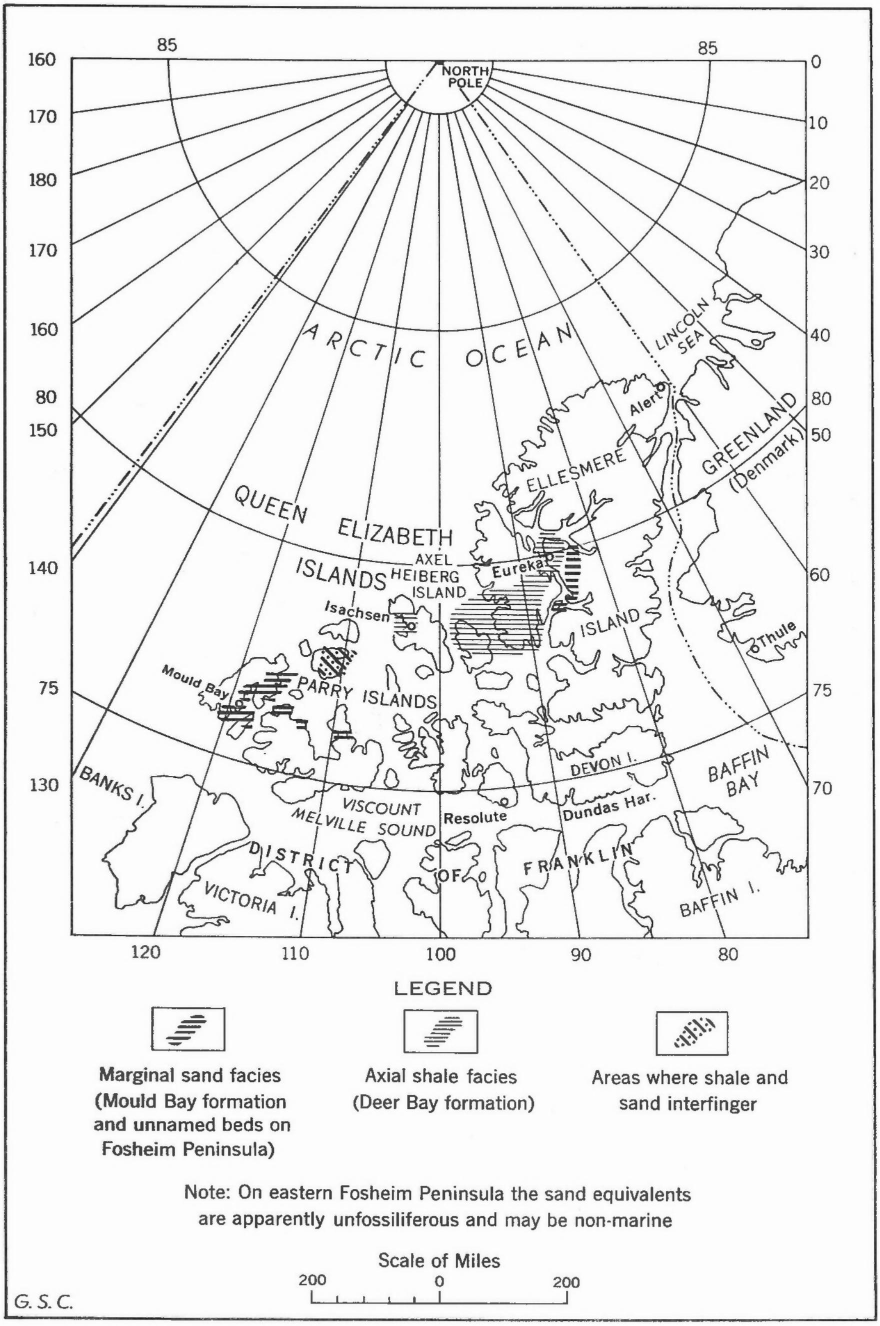

Figure 6. Uppermost Jurassic and lowermost Cretaceous facies belts

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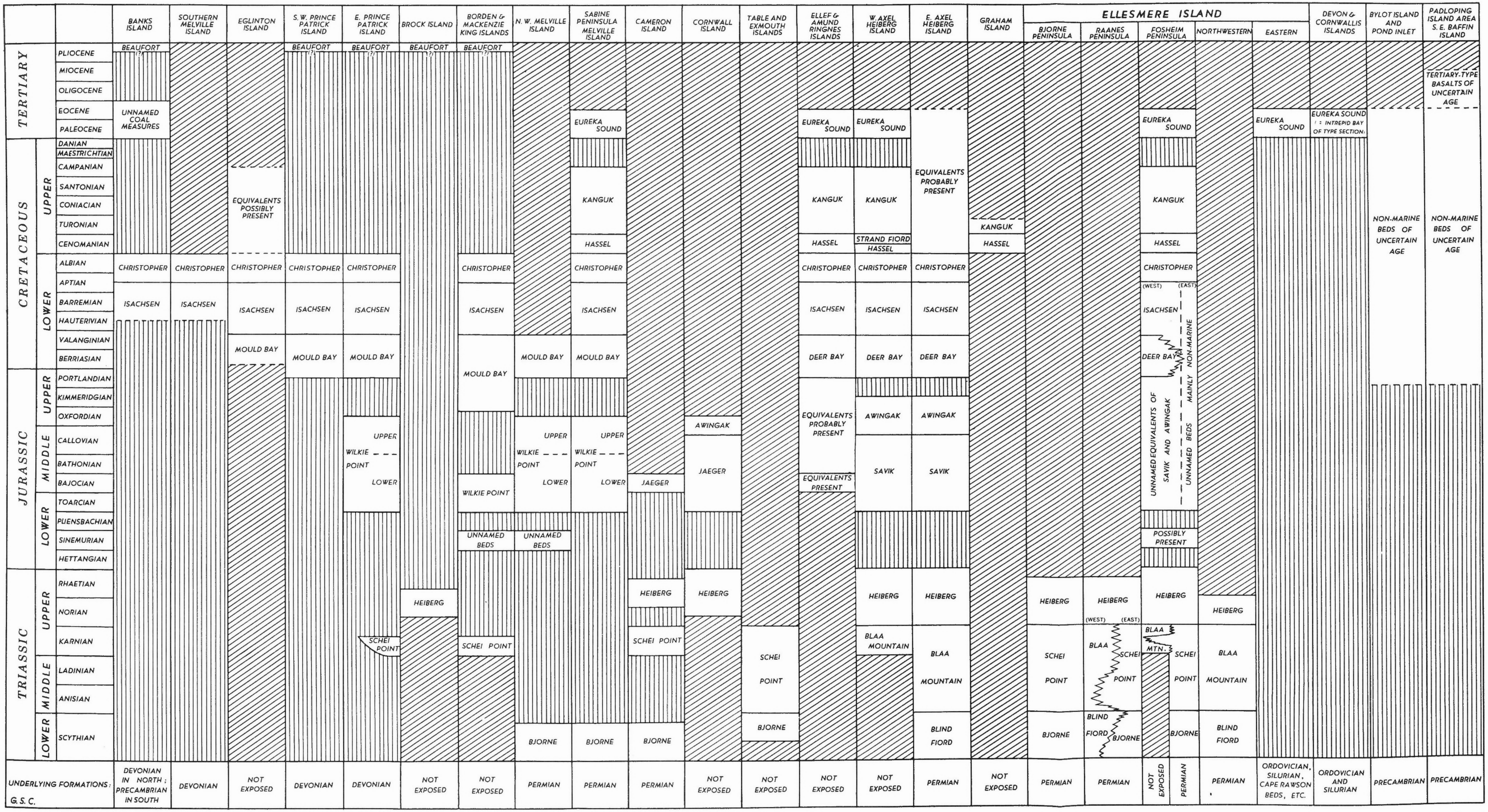
Geological Survey of Canada

Map 1045A: Cornwallis and Little Cornwallis Islands, District of Franklin, Northwest Territories; (1959).

CORRELATION OF MESOZOIC AND TERTIARY FORMATIONS OF THE CANADIAN ARCTIC ARCHIPELAGO



To accompany Paper 60-5, by E. T. Tozer

Printed by the Surveys and Mapping Branch
Published 1960