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PAPER 70-22

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J. A. Jeletzky

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ABSTRACT

Two principal marine biotic provinces existed in Canada throughout the Cretaceous. Faunas of the first or North Pacific Biotic Province were closely related to those of Indo-Pacific, Tethyan and Andean provinces. However, they included some endemic species and genera, others in common with eastern Siberia, Japan, southeastern Alaska and western United States, and yet others in common with the Boreal Province.

In Berriasian through Barremian time the North Pacific Biotic Province was restricted to western Cordilleran and Peace River regions. Thereafter it was restricted to the western Cordilleran region. Marine faunas of North Pacific biotic province mostly include a great variety of ammonites, pelecypods and gastropods. This is particularly true of its Hauterivian-Barremian and Santonian-Maestrichtian faunas. This faunal diversity was probably caused by relatively high water temperature of the Cretaceous seas of that province in Canada.

The second, or North American Boreal Biotic Province is characterized by marine faunas closely similar with or almost identical to those of contemporary Boreal seas of northern Eurasia. In Berriasian to Barremian time this province was restricted to Canadian Arctic Archipelago, northern Yukon, and adjacent parts of Mackenzie District. In Albian time Boreal seas flooded considerable parts of the Canadian Western Interior Region, expanded right across North America, and coalesced with Tethyan seas of Mexican Gulf. This inland sea persisted at least until early Maestrichtian.

Most marine Boreal Cretaceous faunas of Canada are characterized by lack of diversity and scarcity or absence of Tethyan faunal elements. They are mostly dominated by only a few molluscan species found in great abundance. This strong to extreme depauperation was probably caused by abundance of silt and clay particles in and relative coldness of water of the Canadian Boreal seas.

During Cretaceous time the North Pacific and North American Boreal biotic provinces of Canada became increasingly isolated from each other because of gradual but drastic redistribution of land and sea. Endemisms of Berriasian to Aptian marine faunas of these provinces are strongly tempered by presence of numerous common species and genera reflecting the existence of at least two seaways connecting them.

The Vanderhoof and Dawson City seaways connecting the Canadian western interior and Arctic seas with those of Canadian western Cordillera were permanently closed by Mid-Cretaceous (Aptian) orogeny. The ensuing absence of direct marine connections between these basins is reflected in an almost total dissimilarity of their Albian and Upper Cretaceous faunas.

In late Upper Cretaceous the above discussed rearrangement of land and sea was followed by gradual but complete retreat of the sea from Canadian territory. This retreat was apparently concluded before the end of the early Maestrichtian.

MARINE CRETACEOUS BIOTIC PROVINCES AND PALEOGEOGRAPHY OF WESTERN AND ARCTIC CANADA: ILLUSTRATED BY A DETAILED STUDY OF AMMONITES

INTRODUCTION

Cretaceous rocks are widespread in Western and Arctic Canada, including the Prairie Provinces and the western part of the Canadian Arctic Archipelago (*see* Fig. 1). These outcrop-areas include the bulk of Cretaceous marine rocks known in Canada. A few Cretaceous outcrop-areas known in Eastern Canada are represented by nonmarine rocks, except for some little known exposures on the coast of Nova Scotia and on the adjacent parts of the Nova Scotian Shelf beneath the ocean (King *et al.*, 1970). This paper deals, therefore, with biotic provinces and paleogeography of all marine Cretaceous rocks now known in Canada, except for the areally limited, largely submarine Cretaceous rocks of eastern Nova Scotia.

Acknowledgments

The growth of a number of ideas presented in this paper was greatly facilitated by oral and written discussions with many colleagues within and outside the Geological Survey of Canada during the last twenty years. Limitations of space and those of the writer's memory make it impossible to thank all of the individuals in Canada and the United States of America who have furthered the writer's researches in one way or another. Sincere thanks are expressed to all these colleagues.

Sincere thanks are expressed to Drs. D.F. Stott, H.W. Tipper, E.T. Tozer and Mr. T.P. Chamney of the Geological Survey of Canada who provided the writer with valuable published and unpublished information and have patiently answered his numerous queries. Drs. D.F. Stott and E.T. Tozer have, furthermore, critically read the manuscript of this paper.

Special thanks are due to Drs. C.R. Stelck and P.S. Warren of the Geology Department, University of Alberta, Edmonton. In addition to providing valuable published and unpublished information, they have made available a manuscript of their valuable, still unpublished paper "The Significance of the Cretaceous Fossil Succession of Western Canada". Drs. R.W. Imlay and D.L. Jones of the United States Geological Survey have kindly made available a manuscript of their valuable, still unpublished paper on Jurassic and Cretaceous *Buchia* zones in northwestern California and southwestern Oregon.

While acknowledging the above-mentioned assistance, the writer accepts the full responsibility for any statements and conclusions resulting therefrom, except where it is stated otherwise in the text of this paper.

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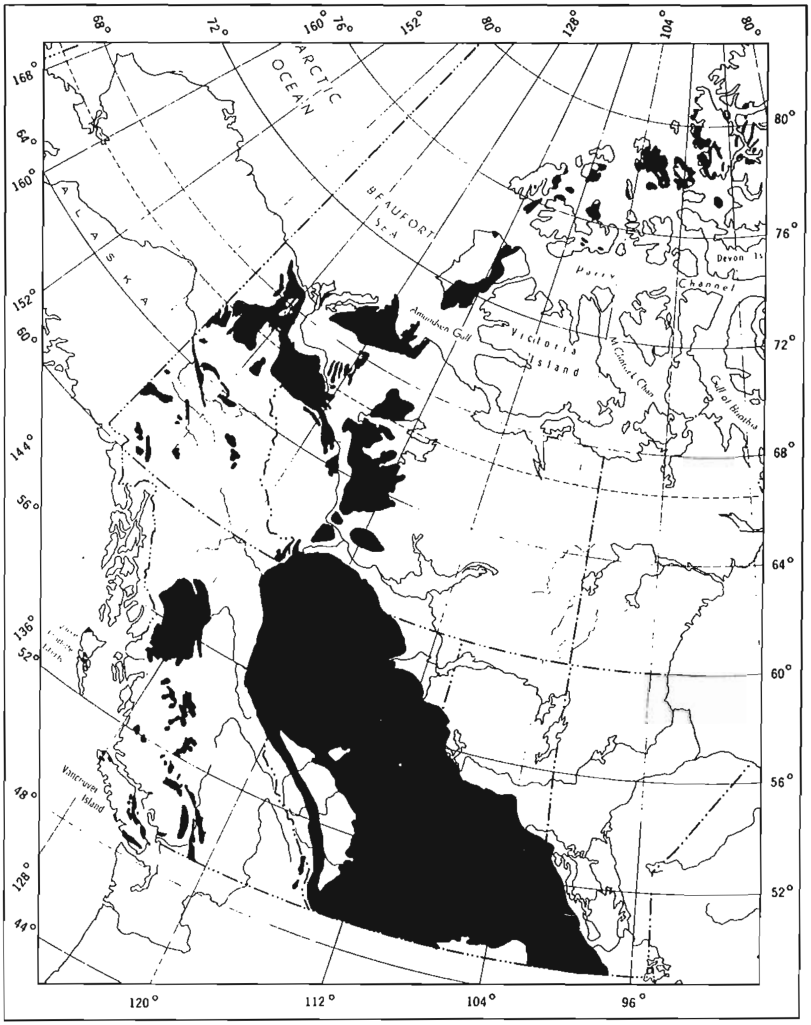


Figure 1. Major outcrop-areas of Cretaceous strata (inclusive of volcanic rocks but exclusive of intrusive rocks) in Western and Arctic Canada. Adapted from GSC Map 1250A. Outcrop-areas in the Canadian Western Cordillera may include locally much undifferentiated Jurassic and/or Tertiary strata. Small outcrop-areas of Cretaceous rocks occur on Ellesmere Island just outside of eastern margin of the map.

The writer expresses sincere thanks to his assistant Mrs. J. Danis who has prepared many of the paleogeographical maps and other illustrations from rough sketches provided by the writer and co-ordinated the drafting of the rest of the illustrations by the Cartographic Unit of the Geological Survey of Canada. Mrs. J. Danis has, furthermore, carefully edited the final draft of the manuscript and assembled the references.

Historical Remarks

Because of an almost total lack of information the text of Schuchert's (1910, pp. 583-598) classical study of the paleogeography of North America contains no information about the Lower Cretaceous paleogeography of Canada and only a few brief references to its Upper Cretaceous paleogeography.

Schuchert's (1910, Pls. 91-93) paleogeographical maps representing various moments of Lower Cretaceous time are of historical interest only as they invariably show all of Canada as an emergent land. The Canadian parts of paleogeographical maps representing the Benton and Pierre epochs of the Upper Cretaceous (Schuchert, 1910, Pls. 94, 95) have, in contrast, a surprisingly modern appearance in recognizing the existence of disconnected Pacific and Western Interior basins and the existence of a lasting connection between the Western Interior basin and the Arctic Ocean across the Mackenzie Lowlands. The paleogeographic map of the Pierre epoch (Campanian-Maestrichtian) is, in fact, much more similar to the maps constructed by the writer (Figs. 17-20) for the same epoch than most of the later paleogeographical maps concerned (including that of Schuchert himself, 1923, p. 229, Fig. 17).

The detailed study of the Cretaceous paleogeography of Canada began with a pioneering study by Dowling (1915) who prepared a series of Upper Cretaceous paleogeographical maps of Alberta and adjacent areas of the Canadian Western Interior Region. Dowling's maps (1915, Pls. I-X) give a basically correct idea about the extent of early to late Cretaceous lands and seas within the region. They also reflect clearly the overall trend toward an eastward expansion of the ancestral Rocky Mountain landmass throughout Upper Cretaceous time coupled with the corresponding eastward and southward retreat of the Upper Cretaceous seas. Even the interruptions of this retreat by temporary advances of the Benton, lower Pierre and upper Pierre seas were clearly recognized by Dowling (1915, Pls. I, III, V, VII).

Because of the scarcity of reliable data about relative ages of the Cretaceous formations concerned, these paleogeographical maps are erroneous in a great many details. For example, they lump all Lower Cretaceous events indiscriminately with the early Upper Cretaceous as the true age of the former rocks was not yet recognized at that time. Dowling's maps are, furthermore, extremely incomplete as little or nothing was known then about the vast area of marine Cretaceous rocks in northern Alberta and northeastern British Columbia.

Schuchert's (1923) classical study "Sites and Nature of the North American Geosynclines ably summarizes the then existing state of knowledge of the Cretaceous paleogeography of Canada.

Schuchert (1923, p. 190, Fig. 14) was apparently the first to conceive of a late Jurassic and ?early Lower Cretaceous marine invasion of the Canadian Western Interior Region from the British Columbia geosyncline. He states: "Here during Cambrian to late Devonian times the Cordilleran trough received no less than 13,000 feet of marine strata. Then the region was warped above sea level, and there are no strata of any kind until late Jurassic time when the overlaps of the British Columbia geosyncline toward the east attained the region of the Mackenzie Valley. The making of the Cordilleran Intermontane geanticline followed, but in this region the arch apparently was not a highland, since to the east of it the Cretaceous deposits do not exceed a few thousand feet in thickness." Schuchert (1923, Figs. 14, 15), furthermore, suggested the existence of a seaway connecting the Pacific late Jurassic and ?early Lower Cretaceous basin with that of northern Yukon across Kluane Ranges, Klondike Plateau and Ogilvie Mountains. At the same time Schuchert (1923, p. 191, Fig. 17) abandoned his earlier idea (Schuchert, 1910, Pl. 95) of the existence of an Arctic outlet of the Pierre sea under the influence of Dowling's (1915) work in Alberta. The interpretation of the Albian paleogeography of Western and Arctic Canada (Schuchert, 1923, p. 190, 191, Fig. 15) is obviously based on McLaren's (1918, 1919) research.

McLearn (1918; 1919, p. 3C) was apparently the first to demonstrate the presence of late Lower Cretaceous marine rocks in the Western Interior Region of Canada and to point out that these Lower Cretaceous formations show no resemblance "either to the Lower Cretaceous of the Pacific coast and Alaska or to the Comanchean of the south", indicating "the presence of barriers of some nature in these directions". These fundamental conclusions have been greatly elaborated upon and emended in a great many details (including a series of paleogeographical maps) in a series of papers published by McLearn (1931, 1932, 1935, 1944, 1945a; McLearn and Kindle, 1950, pp. 130-136) in the following three decades. The acceptance of McLearn's (op. cit.) paleogeographical ideas by Schuchert (1923, pp. 190, 191, Fig. 15; 1955) has made them familiar to geologists and paleontologists the world over.

Many of McLearn's (1919) paleogeographical conclusions are still valid in principle. It seems fair to say that these conclusions form the first firm basis of the Lower Cretaceous paleogeography of Western and Arctic Canada, on which all later workers, including the writer, have built their own investigations.

An important paleogeographical map of earliest Lower Cretaceous time was prepared by Crickmay (1931) in connection with his studies of the Jurassic history of North America.

Dowling's (1915) ideas about the Upper Cretaceous paleogeography of the Canadian Western Interior Region have been developed by L.S. Russell (1939) who brought his conclusions up-to-date and corrected a number of his errors using the modern biochronological data which had become available in the meantime. Dowling's (1915) basic idea of a gradual retreat of the Upper Cretaceous seas toward the south and east interrupted by several short-lived, geologically speaking, rapid northward and westward transgressions found favour with L.S. Russell (1939, pp. 95, 98), albeit in a strongly modified and much elaborated form. This basic concept was favoured in most subsequent studies of the Upper Cretaceous paleogeography of the Canadian Western Interior Region (Reeside, 1957, p. 528; Williams and Burk, Jr., 1964; Caldwell, 1968; Stelck, 1967; Warren and Stelck, unpubl. manuscript). Like L.S. Russell (1939, p. 82, Figs. 1, 2), all these workers believed that the northern outlet of the Upper Cretaceous basin of the Canadian Western Interior Region was permanently closed in the Santonian at the latest.

Teichert (*in* Ruedemann and Balk, 1939, pp. 154-156) was apparently the first to suggest the submergence of a greater part of the Canadian Arctic Archipelago in the Upper Cretaceous and the existence of a seaway connecting this boreal basin with the Disco Bay area of West Greenland across Ellesmere Island. Independently from L.S. Russell (1939) he inferred the existence of another seaway connecting the Upper Cretaceous basin of the Canadian Arctic Archipelago with the Western Interior Region of North America via Mackenzie River basin.

A radically different paleogeographical concept was advanced by Rosenkrantz *et al.* (1942, p. 39) following the discovery of the Coniacian "*Scaphites ventricosus*" fauna on Svartenhuk Peninsula. These workers suggested the existence of a Coniacian and early Santonian seaway connecting Disco Bay basin with that of the Western Interior Region of North America across parts of northern Baffin Island. Like the previous workers, Rosenkrantz *et al.* (1942, p. 40) believed that the seaway connecting the West Greenland basin with that of the Western Interior Region of North America was permanently closed before the late Campanian.

Jeletzky (1950, p. 23) endorsed the paleogeographical concept of Teichert (*in* Ruedemann and Balk, 1939, pp. 154-156) in connection with a study of Canadian *Actinocamax* faunas and their origin. In this connection he questioned the above discussed concept of an early closure of the northern outlet of the Upper Cretaceous basin of Central Canada because of the presence of the Turonian to early Maestrichtian (now known to be late Upper Campanian) marine faunas with strong Western Interior affinities in West Greenland, northern

Siberia, and western Urals. Jeletzky (1950, pp. 23-24) suggested on the basis of these faunal affinities that this seaway remained open during the whole of the Santonian, early Campanian, and in part during the late Campanian and early Maestrichtian.

Warren and Stelck's (1956, 1958, 1961, unpubl. manuscript) studies resulted in recognition of the Pacific affinities of the Berriasian and Valanginian faunas of the Bullhead Group and the persistence of the ancient Triassic to late Jurassic paleogeographical pattern characterized by the Pacific floodings of the Western Interior Region into early Lower Cretaceous time. According to these workers only the Aptian tectonic movements elevated the Central Plateaux of British Columbia and introduced the new paleogeographic pattern characterized by the permanent separation of the Pacific seas of the Western Cordillera from the Boreal seas of the Western Interior.

Stelck *et al.* (1956, pp. 6, 9), Stelck (1958, p. 3) and Warren and Stelck (unpubl. manuscript), furthermore, recognized the initiation of a marine connection between the Boreal seas of Canada and the Tethyan seas of the Gulf Coast in latest middle Albian time.

The paleogeographical sections of Rudkin's (1964) summary of the Lower Cretaceous geological history of Western Canada are mostly based on the paleogeographical work of McLearn, 1944, and McLearn and Kindle, 1950, and ignore almost completely the most important subsequent work of Warren and Stelck (1956, 1958, 1961). This resulted in several paleogeographical misinterpretations already commented upon by Jeletzky and Tipper (1968, p. 83).

The Upper Cretaceous paleogeographical section and maps compiled by Williams and Burk, Jr. (1964) in the same publication are, as already mentioned, largely patterned on those of L.S. Russell (1939) so far as the Western Interior Region of Canada is concerned. The West Cordilleran parts of these paleogeographical maps reflect the then existing scarcity of data about the outcrop-areas and facies of the Nanaimo Group.

The previously discussed strong Western Interior affinities of the Upper Cretaceous marine faunas of West Greenland have been confirmed by the paleontological-stratigraphical studies of Birkelund (1965), who furthermore discovered considerable North Pacific affinities of the Campanian and Maestrichtian ammonite faunas of the region. Birkelund (1965, p. 170, Fig. 125) accordingly endorsed the existence of an unrestricted marine connection between the West Greenland and Western Interior Upper Cretaceous basins from the upper Turonian to the Maestrichtian and suggested the existence of another seaway connecting West Greenland and North Pacific basins in upper Campanian and Maestrichtian time. Following Teichert (*in* Ruedemann and Balk, 1939, pp. 154-156) she envisaged the former seaway as extending around the northern end of the Canadian Shield and across the Mackenzie Lowland.

In connection with a study of the Berriasian and Valanginian Buchias of the Canadian Western Cordillera, Jeletzky (1965a, pp. 56, 61-63, Fig. 3) suggested that the late Berriasian to mid-Valanginian invertebrate faunas of the Pacific slope of North America are distinctive enough from those of the Indo-Pacific and Boreal Realms to be segregated into a new North Pacific faunal Realm.

Sutherland Brown (1966, p. 84, Figs. 6-6, 6-7) published important Lower Cretaceous and late Upper Cretaceous paleogeographical maps of the Insular Tectonic Belt of the Western Cordillera incorporating much previously unpublished data. The late Upper Cretaceous map introduces the idea of existence of two independent embayments of Nanaimo sea on Vancouver Island.

Jeletzky and Tipper (1968) summarized the paleogeography of the Lower Cretaceous of western British Columbia and concluded that the deposition of Lower Cretaceous marine rocks was restricted to two narrow, northwest-trending troughs which were separated from each other by a cordillera-like tectonic landmass except for one or two narrow seaways. The eastern trough was separated from the Western Interior Region by another cordillera-like tectonic landmass pierced by two seaways in the Berriasian to Barremian. One of these seaways connected the Tyaughton Trough (Jeletzky and Tipper, 1968, p. 3) with the seas of northern Yukon while the other connected it with those of northeastern British Columbia. These two seaways were permanently closed by the regional Aptian orogeny. The Cretaceous seas left the mainland of western British Columbia at the end of the Albian time, except for a small area of present Coast Mountains north of Vancouver.

As pointed out by Jeletzky (1968a, p. 55) the Canadian Western Interior seas remained part of the so called Boreal Zoogeographical Province throughout Cretaceous time. The interpretive paleogeographic maps of the Cretaceous of Western and Arctic Canada compiled by Ziegler (1969, pp. 21-24) are much more detailed than any of the earlier paleogeographical maps and incorporate a wealth of the latest stratigraphical, facies and paleontological data. The general paleogeographical concepts of these valuable maps do not differ materially from those advanced by Rudkin (1964) and Williams and Burk, Jr. (1964) and are subject to the same criticisms (*see* Jeletzky and Tipper, 1968, pp. 82-86 and in preceding paragraphs of this section).

The paleogeographical concepts advanced by Jeletzky and Tipper (1968) were elaborated upon by Jeletzky (1970a, 1970c). The existence of North Pacific and North American Boreal Biotic Provinces throughout the Cretaceous was demonstrated by Jeletzky (1970a) in one of these papers.

Peculiarities and Limitations of Paleobiotic Work

Paleobiogeography is not nearly as similar to biogeography in its methods and capacities as its name would imply. The recent biogeographer deals only with the present instant of the immensely long geological time. The chronological framework having been provided ready-made for the biogeographer's use, geological time figures marginally, if at all, among the problems he has to solve. Therefore it is fair to say that the recent biogeographer is fundamentally concerned only with the space.

The geographical framework used by recent biogeographers is provided ready-made in the form of geographical maps and other navigational and hydrographical aids. Furthermore, he mostly works with readily accessible biotic data and can study the geographical and biotic aspects of his subject in fine and finest detail.

None of these conditions of recent biogeographical work apply to paleobiogeography. To begin with, paleobiogeographical research is fundamentally historical in character (e.g. Schuchert, 1910, 1923; L.S. Russell, 1939, p. 81; McLearn, 1944, p. 2; Reeside, 1957, p. 506). Time, in the geological sense, is more important to the paleobiogeographer than is space, as he must first of all recognize the contemporary, geologically speaking, paleobiotic events and segregate them from the next younger and next older biotic events. The success of any reconstruction of paleobiotic provinces depends, therefore, on the availability and reliability of the geochronological (in practice only biochronological; *see* Jeletzky, 1956) standards. Such pre-existing standards are naturally utilized whenever possible. It is often necessary, however, either to adapt them to the requirements and objectives of paleobiotic studies concerned or to develop entirely new biochronological standards in conjunction with them.

Unlike modern biogeographical research the geographical framework needed for paleobiotic studies is, as a rule, not available at the onset of the research. It must be worked out as a part of the project and its validity depends ultimately on the validity of biochronological standards used.

The fundamentally historical nature of paleobiological research and an extremely close interrelation existing between the biochronological, paleogeographical, and paleobiotic data make it imperative to discuss the last in conjunction with paleogeographical and biochronological frameworks.

The precision of paleobiotic work is strongly limited by the unavoidly crude nature of the biochronological time scale. As with paleoecological work discussed by Reeside (1957, p. 506): "Even the shortest intervals (used by paleobiogeographer; writer's comment) are likely to be equal to many "present instants" and his materials do not lend themselves to determination of many important elements. He must usually work with rather large aggregates and without detail. Comparatively, his work is "coarse-grained"."

Unlike the recent biogeographer whose "present instants" are measured in decades or centuries at the very most, the paleobiogeographer has to consider events actually separated from each other by scores of thousands of years, a few hundred thousands and sometimes even a few millions of years as "geologically contemporary". To use events which are only(!) tens of thousands of years apart is usually the very limit of precision for a paleobiogeographer.

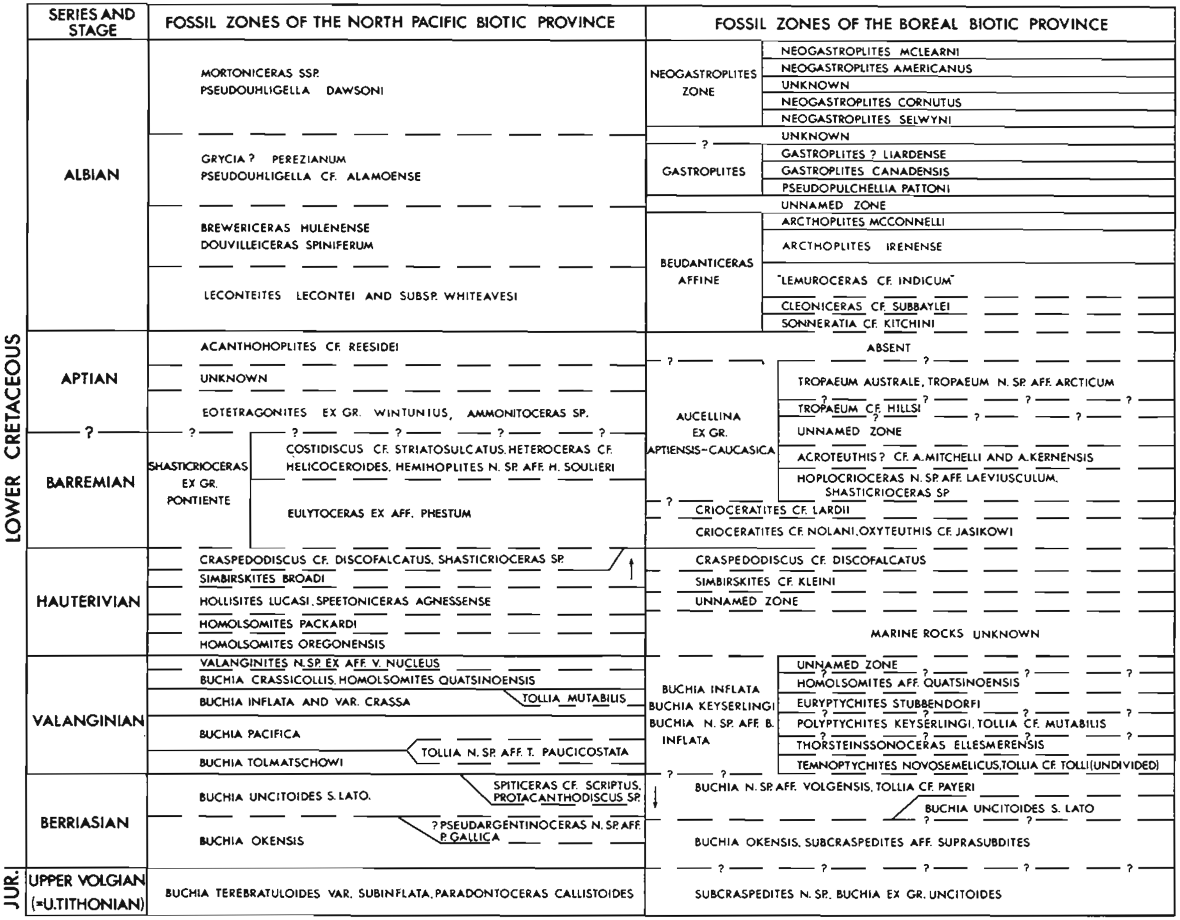
The biogeographical data available for any one of the "geological moments" are few and far between. Many critical data are either not exposed anywhere on the surface of the earth or were utterly destroyed long before the present. The paleobiogeographer must, therefore, limit himself to the reconstruction of the broad to broadest outlines of the paleogeographical elements and paleobiotic provinces without any hope to approach, let alone to match, the "fine grained" work of the recent biogeographer in detail, precision and reliability. His paleogeographical and paleobiotic maps are only pale shadows of their recent counterparts in all respects. As repeatedly pointed out by outstanding students of the subject (McLearn, 1944, p. 2), no outlines of the biotic realms, continents and oceans of the geological past are ever final. Figuratively speaking, they should never be "inked in".

Figures 2 and 3 summarize the biochronological standards (zonal) used by the writer for the Cretaceous rocks of the North Pacific and Boreal Provinces of Canada and their correlation with the international standard.

Biochronology is treated as the only basis of practical geochronology at the fossil zone and stage level (Jeletzky, 1956). Therefore, no attempt was made to integrate the fossil stages and zones proposed in Figures 2 and 3 with the radiometric data. All recent attempts (e.g. Kulp, 1953; Bandy, 1967, pp. 5-6; Pergament, 1967; Kauffman and Kent, 1968, p. 156; Kauffman, 1969, p. 890) to estimate the relative duration of fossil zones and stages in terms of physical (i.e. radiometric) time are deprecated by the writer. The "attractively packaged" results obtained by these workers are unfortunately completely unfounded and highly misleading for average members of the geological and paleontological professions. The latter are often ignorant of the extreme crudeness and often outright unreliability of all presently available radiometric methods of age determination and eagerly accept these quantitative data at their face value being strongly conditioned by the quantitative environment of modern science (Jeletzky, 1965c, p. 135).

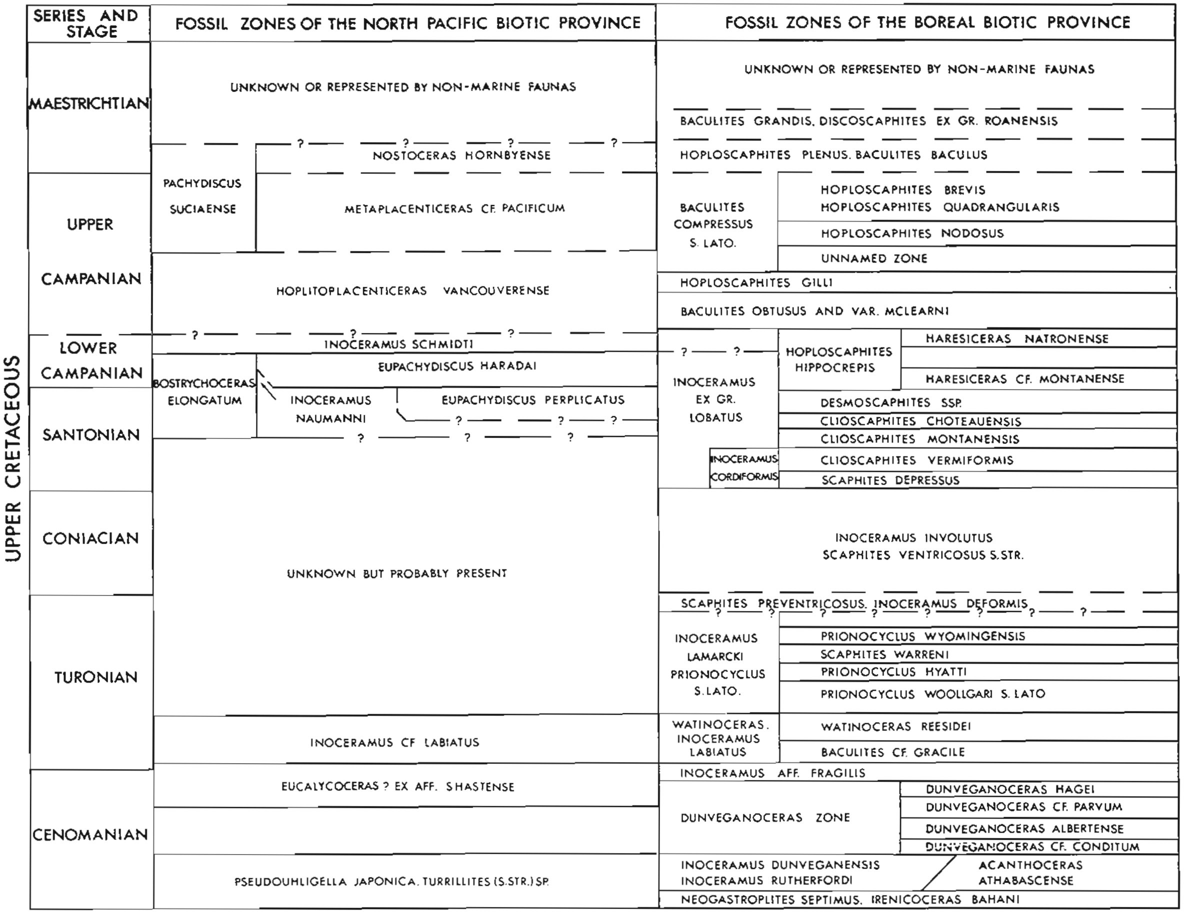
The recent attempts to calibrate the duration of fossil stages and zones are inadmissible. They are based solely on an arbitrary subdivision of larger (allegedly corresponding to the biochronological series or system) intervals of radiometric time into a number of equally long fractions according to the number of zones or stages contained within these intervals. The estimates of durations of these larger intervals of radiometric time being in themselves more or less rough to unreliable, this method piles up one imprecision on top of another. Furthermore it fails to take into account the obviously highly variable rates of evolution of various organisms serving as zonal indices. These irremediable fallacies of the method are unfortunately glossed over by most of its overenthusiastic practitioners. To the writer's knowledge only Casey (1964, p. 193) has frankly stated them and reasonably concluded that "it is too early to reach conclusion regarding the relative length of stages" (in terms of radioactive time; writer's remark).

In the writer's opinion, the statement of Jeletzky (1956, pp. 690-691) that "all available methods of the physical age determination of the layered rocks of the geological standard column, including all radioactive



Series	Series and Stage	Fossil Zones of the North Pacific Biotic Province	Fossil Zones of the Boreal Biotic Province	
LOWER CRETACEOUS	ALBIAN	MORTONICERAS SSP. PSEUDOUHLIGELLA DAWSONI	NEOGASTROPLITES ZONE	NEOGASTROPLITES MCLEARNI NEOGASTROPLITES AMERICANUS UNKNOWN NEOGASTROPLITES CORNUTUS NEOGASTROPLITES SELWYNI
			?	UNKNOWN
		GRYCIA ? PEREZIANUM PSEUDOUHLIGELLA CF. ALAMOENSE	GASTROPLITES	GASTROPLITES ? LIARDENSE GASTROPLITES CANADENSIS PSEUDOPULCHELLIA PATTONI
				UNNAMED ZONE
		BREWERICERAS HULENENSE DOUVILLEICERAS SPINIFERUM	BEUDANTICERAS AFFINE	ARCTHOPLITES MCCONNELLI ARCTHOPLITES IRENENSE "LEMUROCERAS CF. INDICUM"
		LECONTEITES LECONTEI AND SUBSP. WHITEAVESI		CLEONICERAS CF. SUBBAYLEI SONNERATIA CF. KITCHINI
	APTIAN	ACANTHOHOPLITES CF. REESIDEI UNKNOWN EOTETRAGONITES EX GR. WINTUNIUS, AMMONITOCERAS SP.		ABSENT
			AUCELLINA EX GR. APTIENSIS–CAUCASICA	TROPAEUM AUSTRALE, TROPAEUM N. SP. AFF. ARCTICUM TROPAEUM CF. HILLSI UNNAMED ZONE
	? BARREMIAN	SHASTICRIOCERAS EX GR. PONTIENTE: COSTIDISCUS CF. STRIATOSULCATUS, HETEROCERAS CF. HELICOCEROIDES, HEMIHOPLITES N. SP. AFF. H. SOULIERI EULYTOCERAS EX AFF. PHESTUM		ACROTEUTHIS ? CF. A. MITCHELLI AND A. KERNENSIS HOPLOCRIOCERAS N. SP. AFF. LAEVIUSCULUM, SHASTICRIOCERAS SP
			?	CRIOCERATITES CF. LARDII CRIOCERATITES CF. NOLANI, OXYTEUTHIS CF. JASIKOWI
	HAUTERIVIAN	CRASPEDODISCUS CF. DISCOFALCATUS, SHASTICRIOCERAS SP. ↑ SIMBIRSKITES BROADI HOLLISITES LUCASI, SPEETONICERAS AGNESSENSE HOMOLSOMITES PACKARDI HOMOLSOMITES OREGONENSIS		CRASPEDODISCUS CF. DISCOFALCATUS SIMBIRSKITES CF. KLEINI UNNAMED ZONE MARINE ROCKS UNKNOWN
	VALANGINIAN	VALANGINITES N. SP. EX AFF. V. NUCLEUS BUCHIA CRASSICOLLIS, HOMOLSOMITES QUATSINOENSIS BUCHIA INFLATA AND VAR. CRASSA — TOLLIA MUTABILIS BUCHIA PACIFICA BUCHIA TOLMATSCHOWI — TOLLIA N. SP. AFF. T. PAUCICOSTATA	BUCHIA INFLATA BUCHIA KEYSERLINGI BUCHIA N. SP. AFF. B. INFLATA	UNNAMED ZONE HOMOLSOMITES AFF. QUATSINOENSIS EURYPTYCHITES STUBBENDORFI POLYPTYCHITES KEYSERLINGI, TOLLIA CF. MUTABILIS THORSTEINSSONOCERAS ELLESMERENSIS TEMNOPTYCHITES NOVOSEMELICUS, TOLLIA CF. TOLLI (UNDIVIDED)
	BERRIASIAN	BUCHIA UNCITOIDES S. LATO. — SPITICERAS CF. SCRIPTUS, PROTACANTHODISCUS SP. ↓ BUCHIA OKENSIS — ? PSEUDARGENTINOCERAS N. SP. AFF. P. GALLICA	?	BUCHIA N. SP. AFF. VOLGENSIS, TOLLIA CF. PAYERI BUCHIA UNCITOIDES S. LATO BUCHIA OKENSIS, SUBCRASPEDITES AFF. SUPRASUBDITES
JUR.	UPPER VOLGIAN (=U.TITHONIAN)	BUCHIA TEREBRATULOIDES VAR. SUBINFLATA, PARADONTOCERAS CALLISTOIDES	?	SUBCRASPEDITES N. SP., BUCHIA EX GR. UNCITOIDES

Figure 2. Biochronology and Correlation of Lower Cretaceous Rocks of the North Pacific and Boreal Biotic Provinces of Canada.



SERIES AND STAGE		FOSSIL ZONES OF THE NORTH PACIFIC BIOTIC PROVINCE	FOSSIL ZONES OF THE BOREAL BIOTIC PROVINCE
UPPER CRETACEOUS	MAESTRICHTIAN	UNKNOWN OR REPRESENTED BY NON-MARINE FAUNAS ? ? ? ? NOSTOCERAS HORNBYENSE	UNKNOWN OR REPRESENTED BY NON-MARINE FAUNAS BACULITES GRANDIS. DISCOSCAPHITES EX GR. ROANENSIS HOPLOSCAPHITES PLENUS. BACULITES BACULUS
	UPPER CAMPANIAN	PACHYDISCUS SUCIAENSE METAPLACENTICERAS CF. PACIFICUM HOPLITOPLACENTICERAS VANCOUVERENSE ? ? ?	BACULITES COMPRESSUS S. LATO. HOPLOSCAPHITES BREVIS HOPLOSCAPHITES QUADRANGULARIS HOPLOSCAPHITES NODOSUS UNNAMED ZONE HOPLOSCAPHITES GILLI BACULITES OBTUSUS AND VAR. MCLEARNI
	LOWER CAMPANIAN	INOCERAMUS SCHMIDTI EUPACHYDISCUS HARADAI BOSTRYCHOCERAS ELONGATUM	? ? HOPLOSCAPHITES HIPPOCREPIS HARESICERAS NATRONENSE HARESICERAS CF. MONTANENSE INOCERAMUS EX GR. LOBATUS
	SANTONIAN	INOCERAMUS NAUMANNI EUPACHYDISCUS PERPLICATUS ? ? ? ? ? ?	DESMOSCAPHITES SSP. CLIOSCAPHITES CHOTEAUENSIS CLIOSCAPHITES MONTANENSIS CLIOSCAPHITES VERMIFORMIS INOCERAMUS CORDIFORMIS SCAPHITES DEPRESSUS
	CONIACIAN	UNKNOWN BUT PROBABLY PRESENT	INOCERAMUS INVOLUTUS SCAPHITES VENTRICOSUS S.STR.
	TURONIAN		SCAPHITES PREVENTRICOSUS. INOCERAMUS DEFORMIS ? ? ? ? ? ? ? INOCERAMUS LAMARCKI PRIONOCYCLUS S.LATO. PRIONOCYCLUS WYOMINGENSIS SCAPHITES WARRENI PRIONOCYCLUS HYATTI PRIONOCYCLUS WOOLLGARI S. LATO WATINOCERAS. INOCERAMUS LABIATUS WATINOCERAS REESIDEI BACULITES CF. GRACILE
		INOCERAMUS CF LABIATUS	
	CENOMANIAN	EUCALYCOCERAS ? EX AFF. SHASTENSE PSEUDOUHLIGELLA JAPONICA. TURRILLITES (S.STR.) SP.	INOCERAMUS AFF. FRAGILIS DUNVEGANOCERAS ZONE DUNVEGANOCERAS HAGEI DUNVEGANOCERAS CF. PARVUM DUNVEGANOCERAS ALBERTENSE DUNVEGANOCERAS CF. CONDITUM INOCERAMUS DUNVEGANENSIS INOCERAMUS RUTHERFORDI ACANTHOCERAS ATHABASCENSE NEOGASTROPLITES SEPTIMUS. IRENICOCERAS BAHANI

Figure 3. Biochronology and Correlation of Upper Cretaceous Rocks of the North Pacific and Boreal Biotic Provinces of Canada.

methods known to date, are either too crude, or too local in their applicability, or both, to be effectively used as tools of practical everyday geochronology of the layered rocks of the lithosphere", is just as valid today as when it was written. However desirable in principle, the "new biostratigraphy" so ardently advocated by Kauffman and Kent (1968, p. 156) and Kauffman (1969, p. 890) is quite unfounded at present. The same is true of a recent attempt (Bandy, 1967, pp. 5, 6) to abandon the now almost universally accepted bipartite subdivision of Cretaceous time in favour of an entirely new tripartite subdivision allegedly integrating the evolutionary changes of the planktonic foraminifera with the radiometric data. As pointed out by Casey (1964, pp. 197, 198) all radioactive data including those later utilized by Bandy (op. cit.) are either rough or outright unreliable. The latter applies in particular to Kulp's (1953) excessively long estimate of the duration of the Cenomanian Stage uncritically accepted as valid by Bandy (1967, p. 5). This estimate (really a guess) was not admitted either by the Soviet workers (Rubinstein, 1963) or by Casey (1964, pp. 198, 199, Table 2) but their decreased estimates are believed to be just as tentative.

BIOTIC PROVINCES

In his earlier publications the writer (e.g. Jeletzky, 1965a, p. 61; 1968a, p. 55) did not differentiate strictly between the faunal realms and provinces. It is, however, convenient to follow Uhlig (1911), Arkell (1956, pp. 606, 607) and other workers in reserving the term faunal realm for the most comprehensive paleobiotic units each including two or more faunal provinces. The latter can be subdivided, in turn, into the faunally less distinctive and geographically less extensive faunal subprovinces. However, no such attempt shall be made in this paper.

Two principal marine biotic provinces can be recognized in Western and Arctic Canada throughout the Cretaceous. These are the North Pacific Province forming part of the Tethyan Realm and the North American Boreal Province forming part of the Boreal Realm.

North Pacific Province

This term was introduced by Jeletzky (1965a, p. 61, Fig. 3) for the late Berriasian to mid-Valanginian marine faunas of the Pacific slope of North America north of Mexico. It is, however, equally applicable to all other Cretaceous faunas of this region, as pointed out by Jeletzky (1970a).

In Canada, the North Pacific Biotic Province was restricted to Western Cordilleran Region of British Columbia and southern Yukon and the Peace River region in Berriasian and Valanginian time. Thereafter it was restricted to western British Columbia and southern Yukon west of the Central Plateaux Belt.

Outside of Western Canada the North Pacific Province is believed to include the states of Washington, Oregon, California and southeastern Alaska, and the Soviet Far East including Kamchatka and Koriak-Anadyr region (Verestchagin, 1963), and most or all of the Japanese Archipelago.

The concept of the North Pacific Biogeographical Province proposed in this paper seems to be closely similar to that of the informal term "northern part of Pacific Biogeographic Province" proposed by Pergament (1962, p. 55) and Verestchagin (1963, pp. 50, 60-62). However, the writer is opposed to the separation of the Pacific Biogeographic Province or Realm (= oblast' of Soviet literature; *see* Shulgina, 1966, p. 21) from the Tethyan Realm proper advocated by Verestchagin (1963, pp. 50, 60-62), Pergament (1965a, p. 104; 1965b, p. 58; 1966, pp. 5, 6; 1969, p. 106) and some other Soviet workers. This proposal is incompatible with the strong overall similarity of the marine faunas of these Cretaceous "Realms" which correspond in fact to the present day climatic belts.

The far-reaching similarity of all low-latitude Cretaceous marine faunas of the globe and their contrast with those of the Boreal Realm strongly support their retention in the Tethyan Realm and subdivision of this world-wide realm in several faunal provinces (e.g. Indo-Pacific, Atlantic, Andean and North Pacific).

The recent proposal (Saks and Nalniaeva, 1966, p. 189; 1968, p. 80) to include the North Pacific Faunal Province in the Boreal Realm (under the name of the Boreal Pacific Province) is inadmissible. This proposal is based on the Boreal affinities of but a few groups of the Neocomian fossils of the North Pacific Province (Belemnitida and *Buchia* only) and neglects completely the overwhelmingly Tethyan affinities of the rest of its faunas throughout Cretaceous time.

As now known, the marine invertebrate faunas of the North Pacific Province are particularly closely related to those of the Indo-Pacific Province of the Tethyan Realm and to those of the geosynclinal troughs of Mexico and Western South America. The faunal affinities with the European part of the Tethyan Realm are considerably more distant.

The southern boundary of the North Pacific Province is gradational and oscillated somewhat with time but is generally defined by a line drawn through Northern Mexico in North America and immediately south of the Cretaceous outcrop areas of Japan in Asia.

The following qualitative summary of distinctions of the invertebrate faunas of the North Pacific Biotic Province of Western Canada is a progress report only. A number of important invertebrate groups of this province, such as gastropods, corals, echinoids and belemnites are either insufficiently understood or were never studied at all.

Like all Tethyan faunas, the marine invertebrate faunas of the North Pacific Province are much more diversified than those of the Boreal Realm. The common occurrence of phylloceratid, lytoceratid and desmoceratid ammonites is particularly characteristic.

The invertebrate faunas of the North Pacific Biotic Province of Western Canada differ from those of other parts of the Tethyan Realm first of all in the presence of a number of endemic molluscan genera and species.

In the Lower Cretaceous these endemic forms include such ammonite genera and subgenera as *Homolsomites*, *Shasticrioceras*, *Shastoceras*, *Grycia? Argonauticeras*, *Brewericeras*, *Eogunnarites*, *Hulenites*, *Leconteites*, *Parasilesites*, *Moffitites*, *Pseudouhligella*, and several undescribed ancyloceratid (sensu Wright, 1957) genera, trigoniid genera *Quoiecchia* and *Yaadia*, peculiar but mostly undescribed species of *Boreioteuthis* ex gr. *impressa* Gabb, *Grycia? perezianum*, *Eotetragonites* ex gr. *wintunius*, a number of peculiar but still unnamed and undescribed ammonite species, *Buchia tolmatschowi* and *Buchia pacifica* (Crickmay, 1930; Jeletzky, 1965a, 1970a, 1970b; Jeletzky and Tipper, 1968; McLearn, in press and unpublished).

The Upper Cretaceous endemic genera and species include *Pseudouhligella*, *Pseudoxybeloceras*, *Polyptychoceras*, *Ryugasella*, *Canadoceras*, *Metaplacenticeras*, *Neodesmoceras*, *Inoceramus naumanni*, *Inoceramus* (*Schmidtoceramus*) ex gr. *orientalis-schmidti-sachalinensis*, *Inoceramus subundatus*, *I. vancouverensis* (Usher, 1952; Jeletzky, 1967a; Muller and Jeletzky, 1967), a number of other undescribed *Inoceramus* species apparently identical with or closely related to those described from Japan and eastern Siberia, and a number of other insufficiently understood, mostly undescribed invertebrate genera and species.

Another important characteristic of the North Pacific Province is a greater or lesser admixture of genera and species characteristic of the Boreal Realm with the endemic genera and species and the more or less cosmopolitan Tethyan genera and species.

In the Lower Cretaceous these Boreal forms include such ammonite genera and subgenera as *Subcraspedites*, *Tollia*, *Polyptychites*, *Simbirskites*, *Craspedodiscus*, *Hoplocrioceras*, *Tropaeum*, *Arcthoplites*, numerous representatives of such belemnite genera and subgenera as *Arctoteuthis*, *Acroteuthis* and *Boreioteuthis*, a number of *Buchia* species, *Inoceramus colonicus*, *Inoceramus* ex gr. *concentricus-subsulcatus-sulcatus*, and a number of partly undescribed *Inoceramus* species identical with or closely related to those described from northern and eastern Siberia (Jeletzky, 1965a, 1970a; Jeletzky and Tipper, 1968).

In the Upper Cretaceous the Boreal migrants in the North Pacific Province of Western Canada consist mainly of a considerable number of *Inoceramus* species mostly identical with or closely allied to those of northern Eurasia (mostly Siberia).

Other faunal distinctions of the North Pacific Biotic Province of Western Canada include:

1. An apparently complete absence of rudistids;
2. An apparently complete absence of colonial corals and an extreme rarity or complete absence of solitary corals.
3. A rarity of echinoids, except at a few levels where a considerable number of specimens belonging to one or two species of irregular echinoids may be common locally. Such conditions characterize the shallow water facies of the upper Barremian in Manning Park area, lower to middle Albian shales of several areas of the Coast Mountains and the upper Haslam Formation of Nanaimo area.
4. An almost complete absence of sea lilies and starfishes. The old record of *Uintacrinus* from the Haslam Formation of Gulf Islands (Whiteaves, 1904) is the only exception known to the writer.
5. Common to abundant presence of nerineid, naticoid and neritid gastropods which may become rock-forming locally.
6. Common to abundant presence of various Trigoniidae genera in virtually all parts and facies of the Cretaceous column. *Indotrigonia*, *Heterotrigonia*, *Pterotrigonia*, and *Nototrigonia* can be mentioned at present, in addition to the endemic genera *Yaadia* and *Quoiecchia*. However, several other insufficiently understood genera and subgenera of the Indo-Pacific and South American Trigoniidae are common. Trigoniidae may be rock-forming locally, as for example in the late Albian neritic facies of Manning Park area or in the neritic facies of Nanaimo Group on Vancouver Island.
7. An apparently complete absence of any belemnoids in the Aptian, Albian and Upper Cretaceous rocks. This feature is in contrast with the corresponding rocks of the Boreal Realm. However, it seems to be equally characteristic of the whole of Mexico, the western part of Central and South America and most of the Indo-Pacific Province of the Tethyan Realm. The records of Albian and early Cenomanian *Neohibolites* in northern California (Anderson, 1938, 1958) and Japan (Hanai, 1953) are the only known exceptions to this rule.

North American Boreal Province

As it will be shown below, the Boreal marine Cretaceous faunas of Canada differ sufficiently strongly from those of the rest of the Boreal Realm to be segregated in a province of their own. Many of these faunas being equally characteristic of the American part of the Western Interior Region and northern Alaska; the name North American Boreal Province seems to be most appropriate for this new province.

It cannot be overstressed that the term "boreal" is a highly misleading one. The finds of tree-like plants, remnants of large marine reptiles (e.g. D.A. Russell, 1967), and dinosaur tracks in the Cretaceous rocks of high

Arctic regions (e.g. on Spitzbergen, on Mackenzie Lowlands, and in Canadian Arctic Archipelago), clearly indicate at least warm temperate climatic conditions everywhere in the Cretaceous "Boreal" Realm. However, it seems impractical to try to eradicate such a deeply rooted term despite its misleading connotation.

Because of the above considerations the writer deplores the recent introduction (e.g. Saks *et al.*, 1964) of the term "Arctic Province" or "basin" for the circumpolar Mesozoic seas of the Northern Hemisphere situated north of the Boreal Province in a restricted sense. If this "Arctic Province" is sufficiently distinctive from North American Boreal Province, it should be named after some geographical feature within the Arctic Basin (e.g. North Siberian Province; *see* Shulgina, 1966, p. 22).

The North American Boreal Province was restricted to the Canadian Arctic Archipelago and parts of the Yukon Territory and the Mackenzie District of the Northwest Territories, in Berriasian to Aptian time. In the lower to early middle Albian it also included larger areas of the Canadian Interior Plains and the Canadian Eastern Cordillera. In late middle and upper Albian time the North American Boreal seas spread south into the midwestern United States and coalesced with the contemporary Tethyan seas advancing north from the Gulf Region of the United States. This merging of the Boreal and Tethyan seas in the middle of the North American subcontinent greatly altered the faunal character of the North American Boreal Province beginning with early Cenomanian time. The resulting vast midcontinental sea of North America continued to connect the Tethyan seas of the Gulf of Mexico with the Boreal seas of western Greenland and eastern Siberia at least until the end of early Maestrichtian time.

Outside of the midcontinental region of North America the North American Boreal Province includes West Greenland, all of northern Alaska, and at least the easternmost parts of northern Siberia. So far as we know, the southern and western boundaries of the North American Boreal Province in northeastern Asia are gradational and oscillated with time. The western boundary is tentatively placed west of the Lower Cretaceous outcrop areas of the Anabar-Lena region. The southern boundary is placed equally tentatively north of the Koriak-Anadyr region and the Kamchatka Peninsula on the basis of a recent faunal analysis of the Cretaceous faunas of these regions by Verestchagin (1963).

As with the North Pacific Biotic Province of British Columbia, the following summary of the faunal distinctions of the North American Boreal Province of Western and Arctic Canada is a progress report only.

In the Lower Cretaceous the North American Boreal Province was characterized by a greater or lesser endemism of its ammonite, belemnite, *Buchia* and *Aucellina* faunas (Jeletzky, 1964, 1968a and unpublished). Most other pelecypods and all of the gastropods are too little known to permit any meaningful comparison with their relatively well known counterparts in Central Russia, European Arctic, and northern Siberia.

The endemic genera and species of the North American Boreal Province of Western and Arctic Canada include such ammonite genera and subgenera as *Colvillia*, *Grantziceras*, *Gastroplites*, *Neogastroplites*, *Pseudopulchellia* and *Thorsteinssonoceras* (Jeletzky, 1964, 1968a), a number of mostly undescribed and unfigured new species and possibly genera of Ancyloceratidae (sensu Wright, 1957), Puzosiinae, Hoplitidae, Craspeditidae, and Polyptychitinae, a number of mostly undescribed and unfigured cylindroteuthidid belemnite species, several species of *Posidonia*? ex gr. *nahwisi* McLearn, and several undescribed *Buchia* and *Aucellina* species. The prevalence of large to giant forms of *B. okensis* and the presence of representatives of cylindroteuthidid subgenus *Boreioteuthis* are likewise characteristic.

The North American Boreal Province of Western and Arctic Canada is also characterized by an apparently complete absence of true *Buchia volgensis* (Lahusen) and *B. crassicollis* (Keyserling) (Jeletzky, 1970c), general rarity or absence of representatives of Polyptychitinae and their far-reaching replacement by Craspeditidae homeomorphs such as *Thorsteinssonoceras* and *Tollia*, and an apparently complete absence of representatives of the genera *Astieriptychites* and *Bochianites* and those of the family Douvilleiceratidae.

The presence of some characteristic forms of the North Pacific Biotic Province in association with the typical Boreal genera and species constitutes yet another characteristic of the North American Boreal Province of Western and Arctic Canada. Such forms include very rare representatives of *Partschiceras* and *Lytoceras* in the Berriasian and Valanginian, the common occurrence of *Homolsomites* aff. *quatsinoensis* (Whiteaves) and *H.* aff. *bojarkensis* Shulgina in the late Valanginian, the occurrence of *Shasticrioceras* sp., *Hoplocrioceras* n. sp. ex aff. *H. laeviusculum* (Koenen), *H.* cf. *remondi* (Gabb) and *Ancyloceras* (*new subgenus?*) ex aff. *starrkingi* (Anderson) in the Barremian (Jeletzky, 1964, 1968a and unpublished).

Other characteristic features of the North American Boreal Province include:

1. Occurrence of a cylindroteuthidid subgenus *Arctoteuthis* in the Berriasian to Hauterivian, and possibly Barremian, rocks. This is in contrast with the European part (Atlantic Province) of the Boreal Realm where this subgenus is restricted to the Upper Jurassic rocks (Saks and Nalniaeva, 1966, pp. 168-191).
2. An apparently complete absence of any corals and echinoids.
3. A complete absence of rudistids and an extreme rarity of any heavily hinged pelecypods with exception of representatives of genera *Inoceramus* and *Arctica*.
4. An apparently complete absence of representatives of Trigoniidae, with the exception of *Pterotrigonia albertensis* McLearn in the late lower Albian rocks of the lower Athabasca area.
5. An apparently complete absence of the nerineid and neritid gastropods and an extreme rarity of gastropods in general.
6. An extreme rarity of sea lilies and starfishes, with the exception of some Aptian and late middle Albian beds.
7. An apparently complete absence of belemnitids in the Aptian and Albian rocks.
8. An almost complete absence of brachiopods.

Generally speaking, the Lower Cretaceous invertebrate faunas of the North American Boreal Province of Western and Arctic Canada are characterized by their lack of diversity. These strongly to extremely depauperated faunas are, as a rule, dominated by only a few, or even a single, molluscan species that occur in a great abundance. This depauperation distinguishes them sharply from those of the North Pacific Biotic Province of Western Canada. To a lesser extent the same is true of the European, European Arctic, and western Siberian (Atlantic Province) parts of the Boreal Realm, which are characterized by somewhat less depauperated faunas of marine invertebrates.

The extreme faunal depauperation of the Boreal Lower Cretaceous seas of Western and Arctic Canada was probably caused by a relative coolness of the water as compared to more southerly and westerly regions of North America and to other parts of the Boreal Realm.

The strongly provincial late middle to upper Albian invertebrate faunas of the North American Boreal Province were only slightly affected by the opening of a seaway connecting the latest middle Albian seas of the Western Interior Region of Canada with those of the Gulf Coast of the United States (Stelck *et al.*, 1956, pp. 6, 10). However, a considerable number of Tethyan and cosmopolitan faunal elements began to penetrate into this Boreal basin in early Cenomanian time (Warren and Stelck, 1958). These southern migrants mingled there with the gradually evolving endemic faunal elements and with the Boreal migrants which penetrated into the midcontinental Boreal seas of Canada from the north. Such southern and northern migrations continued throughout the remainder of the Upper Cretaceous and resulted in a considerable diversification of the Cenomanian to lower Maestrichtian invertebrate faunas of the Western Interior seas of Canada as compared with their late middle and upper Albian counterparts.

The Upper Cretaceous faunas of the Western Interior seas of Canada are always characterized by an abundance and variety of the scaphitid and baculitid ammonites. Most of these heteromorphs belong to endemic lineages derived from a few cosmopolitan or Tethyan root forms. *Scaphites* ex gr. *patulus-depressus*, *Clioscaphites*, *Desmoscaphites*, *Pteroscaphites*, *Rhaebocaras*, *Ponteixites*, *Discoscaphites* ex gr. *abyssinis-cheyennensis-mandanensis*, *Hoploscaphites* ex gr. *gilli-nicolleti*, *Haresiceras*, *Baculites* ex gr. *haresi* and *Baculites* ex gr. *compressus* belong to this group. These forms are among the most distinctive faunal elements of the North American Boreal Province.

Some other scaphitids and baculitids, such as *Hoploscaphites hippocrepis*, *Sciponoceras*, *Baculites* cf. *besairiei*, *Baculites* ex gr. *baculus-clinolobatus*, are unrelated shortlived migrants fron the Tethyan Realm. Representatives of *Otoscaphites* are North Pacific migrants via northern Alaska.

Ammonites, other than scaphitids and baculitids, are rather rare in the mid- to late Upper Cretaceous rocks of the Western Interior of Canada, although they are reasonably abundant in the Cenomanian and Turonian rocks of the region. Some of these, as for example *Dunveganoceras* and possibly *Prionocyclus* (including *Collignoniceras* and *Selwynoceras*), appear to form endemic lineages and are extremely distinctive paleobiogeographically. Others, such as *Metoicoceras*, *Placenticeras*, *Acanthoceras*, *Watinoceras*, *Didymoceras*, and *Borissiakoceras* appear to be short-lived migrants from the south.

Belemnites are extremely localized and mostly rare (Jeletzky, 1950). All of them appear to be short-lived migrants from the European part (Atlantic Province) of the Boreal Realm via western Greenland and the Canadian Arctic Archipelago.

The character of the Upper Cretaceous pelecypod fauna does not seem to differ materially from that of the Lower Cretaceous fauna.

Representatives of the genus *Inoceramus* are abundant and varied throughout the Upper Cretaceous column. They include some endemic forms (e.g. *I. rutherfordi* and *I.* ex gr. *corpulentus*), a few North Pacific migrants (e.g. *I. stantoni*) and many cosmopolitan forms (e.g. *I. labiatus*, *I.* ex gr. *lamarcki*, *I.* ex gr. *deformis*, *I.* ex gr. *cordiformis*, *I.* ex gr. *balticus*). Some other subgenera and species appear to be Boreal migrants from the European part (Atlantic Province) of the Boreal Realm (e.g. *Sphenoceramus*, *Volviceramus*, *Tenuipteria*). They may have reached the Western Interior Basin of Canada either via western Greenland or via northern Siberia and Alaska.

Pelecypods other than *Inoceramus* are relatively rare and mostly of distinctly Boreal affinities. Heavily shelled and richly ornamented characteristically Tethyan taxa, such as *Gryphaea*, *Pycnodonta*, *Exogyra*, rudistids and Trigoniidae, are extremely rare or absent. *Exogyra columbella* and *Arctostrea* ex gr. *lugubris* (Jeletzky, 1968a) are notable exceptions of this rule.

Gastropod faunas appear to be extremely depauperate and localized. No representatives of nerineid or neritid gastropods are known in the Upper Cretaceous rocks of the Western Interior of Canada.

Echinoids, sea lilies, brachiopods, and crustaceans are extremely rare and corals appear to be completely absent.

On the whole the Upper Cretaceous faunas of the Canadian part of the North American Boreal Province are characterized by a mixture of the prevalent Boreal and endemic faunal elements with minor Tethyan and cosmopolitan elements. North Pacific and Indo-Pacific faunal elements are almost completely lacking in the Canadian part of the province.

The Tethyan and cosmopolitan faunal elements are strongly reduced in the Canadian part of the province as compared to the equivalent faunas of the

United States Western Interior Region. This is well illustrated by an apparently complete absence of *Calycoceras*, *Tragodesmoceras*, *Neocardioceras*, *Thomasites*, *Vascoceras*, *Barroisiceras*, *Binneyites*, *Texanites*, *Placenticeras guadalupae*, *Phlycticrioceras*, *Pachydiscus*, *Menuites*, *Solenoceras*, *Exiteloceras*, *Emperoceras*, *Sphenodiscus*, *Coahuilites*, *Inoceramus undulatoplicatus*, *Marsupites*, *Gryphaea*, most *Exogyra* and rudistids, and all Trigoniidae in Canada in spite of their occurrence south of the International Border (compare Cobban and Reeside, 1952 and Jeletzky, 1968a). All these Tethyan forms are, furthermore, known to become progressively scarcer northward between the Gulf Coast and the Canadian Boundary.

The above described distinctions of the Upper Cretaceous faunas of the Canadian part of the province from their American counterparts are not sufficiently strong for a subprovincial differentiation of the two. So far as known, these faunal distinctions are restricted either to a gradual northward depauperation or disappearance of above mentioned southern elements or an equally gradual southward depauperation or disappearance of the northern elements (e.g. *Inoceramus* ex gr. *lobatus-cardissoides-patootensis*, *Dunveganoceras*). Otherwise, there are little or no generic or even specific distinctions between the Upper Cretaceous faunas of the Canadian and American parts of the province.

COMPARISON OF CRETACEOUS AMMONITE FAUNAS OF NORTH PACIFIC AND BOREAL PROVINCES

Ammonites have been selected for a detailed, so far as possible quantitative (Fig. 4 and Tables 1-11), illustration of the faunal distinctions of marine Cretaceous biotic provinces of Western and Arctic Canada which were briefly and strictly qualitatively outlined in the preceding sections. This selection reflects the relative abundance of ammonites in most Cretaceous stages (Jeletzky, 1964; 1965a; 1968a, pp. 2, 3; 1970a; Muller and Jeletzky, 1967, 1970; McLearn, in press; Jeletzky, and Tipper, 1968), the more satisfactory state of our knowledge of the Cretaceous ammonite faunas of Canada as compared with that of any other major group of Cretaceous marine invertebrates, and last but not least the writer's personal familiarity with the Cretaceous ammonite faunas of Western and Arctic Canada.

The genus was selected as the basic taxonomic unit for the purpose of this comparison. The use of ammonite species would have been preferable. It was impractical, however, because only a few ammonite species are known to be common to the Cretaceous North Pacific and Boreal Provinces of Canada (*see* Figs. 2, 3).

The writer's concept of ammonite genera and subgenera is much more conservative than that of the ammonite volume of the Treatise on Invertebrate Paleontology (Arkell *et al.*, 1957). It is elucidated by the writer's recent publications dealing with the Cretaceous ammonite faunas of Western and Arctic Canada (Jeletzky, 1964, 1965a, 1965b, 1966, 1968a; Jeletzky and Tipper, 1968; Muller and Jeletzky, 1967, 1970) where many genera considered to be valid by Arkell *et al.* (1957) are either downgraded to subgenera or placed into synonymy of other genera. This expressly conservative approach to the ammonite classification is reflected less strongly in this paper than in other publications of the writer. No distinction is made between ammonite genera and subgenera in this chapter for the sake of simplicity and all subgenera considered to be valid by the writer are herein treated as full genera. The above mentioned taxonomic approach must, nevertheless, be constantly kept in mind as it introduces a strong subjective element into this study.

The lists of ammonite genera occurring in the individual Cretaceous stages and substages of the North Pacific and Boreal Provinces of Canada are largely based on the personal identification of Cretaceous ammonites collected by officers of the Geological Survey of Canada (including the writer) and by

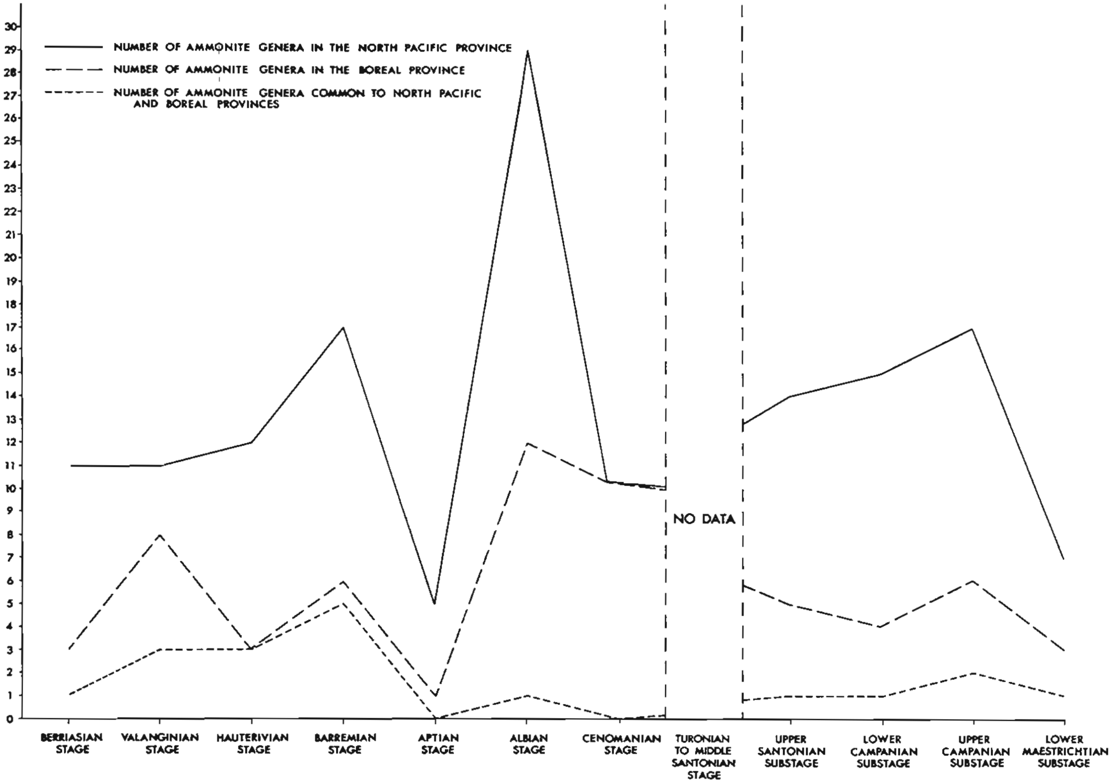


Figure 4. Comparison of the Cretaceous ammonite faunas of the North Pacific and North American Boreal Biotic Provinces.

staff members of various other Canadian organizations. A number of these ammonite genera have been listed, discussed and/or illustrated in the writer's reports (Jeletzky, 1950, 1958b, 1960, 1961a, 1961b, 1964, 1965a, 1965b, 1966, 1968a, 1970a, 1970b; Jeletzky and Tipper, 1968; Muller and Jeletzky, 1967, 1970). Many other genera are only listed in various published geological reports of the Geological Survey of Canada. Other genera have been identified in unpublished fossil reports of the writer and are published in this paper for the first time.

The literature data have only been used in the cases of Canadian or related foreign ammonite faunas not personally studied by the writer. The sources of this information are always clearly identified in the text of this paper.

International Cretaceous stages and substages have been selected as basic biochronological units for the purpose of this comparison. The admittedly desirable use of fossil zones would introduce far too many complicating details. It is, furthermore, often made impossible by the scarcity of ammonite species, or for that matter, of any other biochronologically valuable marine invertebrate species (excepting Berriasian and Valanginian *Buchia* species, Valanginian to Barremian ammonites, and Albian *Aucellina* species; *see* Jeletzky, 1964, 1965a, 1966, 1968a), common to the North Pacific and Boreal Cretaceous Biotic Provinces of Canada. This circumstance strongly complicates the zonal correlation of marine rocks of these two provinces and makes it rather uncertain in many instances (*see* Figs. 2, 3). It is, however, usually possible to recognize at least the approximate positions of the boundaries of the international Cretaceous stages and substages in the two biotic provinces concerned by an independent correlation of their faunas with those of the classical European Cretaceous sections (Jeletzky, 1970a).

The use of international standard stages and substages as basic biochronological units for the purpose of this comparison of the Canadian ammonite faunas unfortunately necessitates lumping together genera belonging to several individual ammonite faunas. As illustrated by Figures 2 and 3, the numbers of individual faunas so lumped vary strongly and irregularly from one stage to another within each of the biotic provinces concerned. The number of fossil zones recognizable within the individual stages often varies from one province to another (*see* below). This diminishes more or less strongly, and sometimes obscures completely, the actual values of the characteristic discrepancy existing between the number of ammonite genera occurring in the individual Cretaceous faunas of the North Pacific and Boreal Provinces of Canada.

In Albian and Upper Cretaceous times the actual values of the characteristic discrepancy between the number of ammonite genera occurring in the individual Cretaceous faunas of the North Pacific and Boreal Provinces of Canada are further diminished by the considerably faster turnover rate (*see* pp. 32-34) of the ammonite genera in the Boreal Province. Because of these negative factors, the actual discrepancies between the number of ammonite genera must be considerably greater than indicated by their tabulation in Figure 4 and Tables 1-11. Some estimates of probable influence of these two negative factors are given in connection with the discussion of the ammonite faunas of all better known Cretaceous stages.

The above discussion of the nature of paleontological data used in this study should suffice to indicate that an attempt at a detailed comparative analysis (especially a quantitative one) of any major faunal group is strongly complicated by the prevailingly qualitative and often outright subjective nature of the data available. This was already stressed by the writer (Jeletzky, 1965c) in connection with the analysis of the qualitative and non-calibrated nature of biochronological correlation. The same point was made more recently by House (1967, pp. 41, 42) in connection with the analysis of the fluctuations in the evolution of Paleozoic invertebrates.

So far as this study is concerned, the reader must realize that despite the attempt at a quantitative presentation of critical data (i.e. tabulation and comparison of the numbers of ammonite genera known to occur in the individual Cretaceous stages of the North Pacific and Boreal Provinces of Canada) the results obtained are semiquantitative under the best of circumstances and can only be judged to be valid if they do not contradict several other essentially qualitative considerations discussed in the preceding pages. As indicated in the individual sections of this chapter, any attempt at a rigorously statistical evaluation of the numerical data or an attempt to ignore other qualitative factors involved, is apt to produce misleading to outright erroneous results.

Berriasian Stage

The almost total dissimilarity of the Berriasian ammonite faunas of the North Pacific and Boreal Provinces of Canada is illustrated by the following table.

Table 1

Berriasian Stage	
North Pacific Province	Boreal Province
Total 11 genera	Total 3 genera
*Subcraspedites**	
Spiticeras	
Pseudargentinoceras?	
Protacanthodiscus	
Negreliceras	
Neocomites	
Masenoticeras?	
Lytoceras	
Hypophylloceras	*Subcraspedites**
Hemilytoceras	*Tollia*
Groebericeras	*Partschiceras*
Common genera (marked by an asterisk) 1	

It appears to be a reasonably correct reflection of the actual state of affairs rather than a statistical artifact caused by an extremely fragmentary state of knowledge of the faunas concerned as the better known (Anderson, 1945; Jones, Bailey and Imlay, in press) Berriasian ammonite faunas of the Pacific slope of the United States are devoid of any common genera with the Canadian Boreal Province.

The almost total dissimilarity of the Berriasian Boreal and North Pacific ammonite faunas cannot be explained by the geographical isolation of the Arctic basins of Canada from those of the Western Cordillera because of a far-reaching specific similarity of the Berriasian *Buchia* faunas of these same basins (Jeletzky, 1964, 1965a, 1966). It is more likely that the relatively restricted nature of seaways connecting these basins (Fig. 5) accentuated the climatic differences between North Pacific and Boreal provinces sufficiently to inhibit any major exchange of their ammonite faunas. Boreal *Buchia* and belemnite species were apparently much more tolerant of these climatic differences and were consequently able to migrate freely into marine basins of northeastern and western British Columbia. The penetration of _Subcraspedites_ into the North Pacific Province suggests the greater temperature tolerance of the Craspeditidae as compared with that of other ammonites.

Only one ammonite genus is, as a rule, represented in the individual ammonite faunas of the Boreal Province. The individual ammonite faunas of the Pacific Province include, in contrast, anywhere between 3 and 6 genera. The presence of a unique phylloceratid specimen (_Partschiceras_ sp.) in the lower Berriasian of Mackenzie King Island (Jeletzky _in_ Tozer and Thorsteinsson, 1964, p. 145) suggests that some Tethyan ammonites at least were able to penetrate into the Boreal Province of Arctic Canada. _Partschiceras_ is a typical Tethyan genus and its apparent absence in the Canadian North Pacific Province obviously is a matter of a collecting failure only.

Valanginian Stage

The following tabulation of the ammonite genera hitherto known from the Valanginian rocks of the North Pacific and Boreal Provinces of Canada clearly reflects a much stronger commingling of their faunas as compared with Berriasian time. This commingling is furthermore accompanied by a sharp increase of the relative number of ammonite genera in the Canadian Boreal Province.

Table 2

Valanginian Stage	
North Pacific Province	Boreal Province
Total 11 genera	Total 8 genera
Valanginites	
_Tollia_*	
Thurmannites	
Sarasinella	_Virgatoptychites_
Partschiceras	_Tollia_*
_Polyptychites_*	_Thorsteinssonoceras_
Olcostephanus	_Temnoptychites_
Neocomites	_Polyptychites_*
Hypophylloceras	_Lytoceras_ s. str.
Hemilytoceras	_Homolsomites_*
_Homolsomites_*	_Euryptychites_
Common genera (marked by an asterisk) 3	

The total of 8 genera occurring in the Valanginian rocks of the Canadian Boreal Province comprises no less than 72 per cent of those occurring in the contemporary rocks of the Canadian North Pacific Province. This low depauperation ratio is unmatched even in the Albian Stage in spite of the absolutely greater number of ammonite genera (11) recorded from its Boreal Province.

In the writer's opinion the far-reaching commingling of the Valanginian ammonite faunas was largely caused by a widespread Valanginian transgression (Fig. 6) rather than by any far-reaching levelling off of the climatic conditions in the north-south direction. This is indicated by the circumstance that the ratio of genera common to both provinces remains low and that none of the Tethyan ammonite genera (e.g. *Valanginites*, *Thurmannites*, *Sarasinella*, *Olcostephanus*, *Neocomites*, *Hypophylloceras*, *Hemilytoceras*) occurring in the North Pacific Province of Canada is known from the Boreal Province. Most of these genera are, furthermore, much less common in the Canadian part of the North Pacific Province than they are farther south. The record of *Lytoceras* s. str. in the Boreal Province is actually much less significant than it appears to be statistically, being based on a few specimens found in the Sverdrup Basin. The commingling of ammonite faunas was therefore almost exclusively limited to the representatives of Polyptychitinae and Craspeditidae. It consisted of a mass migration of a few typical Boreal genera (e.g. *Tollia* and *Polyptychites*) into the North Pacific Province and of a subsequent mass migration of some of their North Pacific descendents (e.g. *Homolsomites*) into the North American Boreal Province in the wake of a strong Valanginian transgression. It can be assumed that the Valanginian representatives of Polyptychitinae and Craspeditidae were characterized by an exceptionally great temperature tolerance which enabled them to migrate relatively freely in and out of the North Pacific Province. It should be noted in this connection that the Valanginian *Buchia* faunas of the Canadian provinces concerned are less similar (Jeletzky, 1965a, p. 61) than their Berriasian *Buchia* faunas. This progressive differentiation of *Buchia* faunas supports the conclusion about the persistence of the climatic distinctions between the Boreal and North Pacific Provinces of Canada based on the comparison of their ammonite faunas.

Hauterivian Stage

The following table summarizes the ammonite genera hitherto known from the Hauterivian rocks of the North Pacific and Boreal Provinces of Canada.

Table 3

Hauterivian Stage	
North Pacific Province	Boreal Province
Total 12 genera	Total 3 genera
Spitidiscus	
Speetoniceras	
Shasticrioceras	
*Simbirskites**	
Partschiceras	
Hypophylloceras	
Hoplocrioceras	
Homolsomites	
Hollisites	
Hemilytoceras	*Simbirskites**
*Craspedodiscus**	*Craspedodiscus**
*Crioceratites**	*Crioceratites**
Common genera (marked by an asterisk) 3	

The extreme paucity of the Hauterivian ammonite fauna of the Canadian Boreal Province as compared with its North Pacific counterpart appears to reflect, in part, a cooling of the Boreal Province as compared with Valanginian time rather than an increased geographical isolation of the two. This is indicated by a total absence of all typically Tethyan ammonite genera in the Boreal Province. The fact that all three ammonite genera hitherto known from the Canadian Boreal Province also occur in its North Pacific counterpart indicates direct and easy connection between the two. There is, furthermore, good reason to believe that other simbirskitid and ancyloceratid (sensu Wright, 1957) genera (e.g. *Speetoniceras*, *Hollisites*, and *Hoplocrioceras*) reached the Canadian part of the North Pacific Province via the Canadian Boreal Province. These genera are essentially restricted to the Boreal Province of northern Eurasia. Their absence in the intervening marine Hauterivian basin of the northern Yukon (Fig. 7) should therefore be merely a result of a collecting failure. Another contributing factor to the paucity of the Boreal Hauterivian ammonite faunas in Canada seems to have been the strong regression of the Canadian nongeosynclinal Boreal Hauterivian seas as compared with the Valanginian ones (Figs. 6, 7).

It should be pointed out that the genus *Wellsia* Imlay is treated as a junior subjective synonym of *Homolsomites* and the genus *Hertleinites* is treated as a junior subjective synonym of *Craspedodiscus*. The restriction of lower Hauterivian representatives of *Homolsomites* to the North Pacific Province of Canada appears to be due to the apparent absence of marine rocks of that time in the Canadian Boreal Province (*see* Fig. 7).

Barremian Stage

In spite of a somewhat fragmentary state of knowledge, the Barremian ammonite fauna of the Canadian North Pacific Province is extremely diversified (Table 4). The generic diversification of this fauna compares favourably with that of the closely related Barremian faunas of northern California (Murphy, 1956, Popenoe *et al.*, 1960) and South America. The absence of *Pulchellia* (including subgenus *Nicklesia*) in British Columbia and the absence of *Costidiscus*, *Heteroceras*, and *Toxoceratoides*? in northern California appear to be a subprovincial distinction (climatic) rather than the result of a collecting failure.

The number of ammonite genera per individual Barremian fauna of the Canadian North Pacific Province fluctuates between three and eight.

Unlike the Hauterivian ammonite fauna, the Barremian ammonite fauna of the Canadian Boreal Province lacks any distinctively Boreal genera and is a depauperated version of the Barremian North Pacific fauna (Table 4). The composition of the Barremian Boreal fauna appears to reflect an improvement of climatic conditions in the North American Boreal Province of that time perhaps facilitated by the continuation of the Hauterivian-Barremian transgression in the geosynclinal belt (Fig. 7, p. 40). The depauperation of the Barremian Boreal ammonite fauna in Canada may also reflect, in part, the strongly regressive nature of the nongeosynclinal Barremian Boreal seas closely resembling that of the Boreal Hauterivian seas (Fig. 7). Like the late Hauterivian seas, the Boreal Barremian seas were essentially restricted to the northern Yukon and the northwest part of the Mackenzie District (Jeletzky, 1961b, pp. 537, 539; 1968a, p. 10).

With the exception of *Aconeceras*, which is common to the Boreal and Tethyan Realms the world over, all Barremian ammonite genera of the Canadian Boreal Province belong to a single family Ancyloceratidae Meek, 1876 sensu Wright, 1957. All these ancyloceratid genera appear to be facies and/or temperature-tolerant immigrants from the Tethyan Faunal Realm, even though some of them (e.g. *Hoplocrioceras*) may have reached the Canadian Boreal basins via Boreal basins of northern Europe and Siberia.

Table 4

Barremian Stage	
North Pacific Province	Boreal Province
Total 17 genera	Total 6 genera
Toxoceratoides?	
_Shasticrioceras_*	
Partschiceras	
_Hoplocrioceras_*	
Hemihoplites	
Hemibaculites	
Heteroceras	
Hamitoceras	
Hamulina	
Protetragonites	
Eulytoceras	
Eotetragonites	_Shasticrioceras_*
Costidiscus	_Pedioceras_
Argonauticeras?	_Hoplocrioceras_*
_Ancyloceras_*	_Ancyloceras_*
_Acrioceras_*	_Acrioceras_*
_Aconeceras_*	_Aconeceras_*
Common genera (marked by an asterisk) 5	

The inferred predominantly northward migration of the Barremian ammonites in Western and Arctic Canada represents an important reversal of the prevalent direction of migration of ammonite faunas as compared with that of the Valanginian-Hauterivian times, which was predominantly southward (_see_ previous sections). This reversal of migration direction probably was connected with the extremely strong depauperation of the Boreal ammonite faunas (consisting largely of Craspeditidae and Olcostephanidae genera) during and at the end of Hauterivian time. This near extinction of the Boreal ammonite faunas at the Hauterivian-Barremian boundary was presumably caused by the warming up of the Boreal Realm. This climatic change must have facilitated the northward migration of those Ancyloceratidae genera best adapted to fill out the ecological niches which became vacant in the Canadian (and Eurasian) Boreal basins.

The presence of _Pedioceras_ (=_Pseudocrioceras_) in the Canadian Boreal Province and its apparent absence in the North Pacific Province should be ascribed to a collecting failure. _Pedioceras_ is well represented in the Barremian Tethyan seas of Central and South America and probably migrated into the Canadian Boreal Province via geosynclinal basins of the Pacific slope of North America.

According to American workers (Murphy, 1956, 1969; Popenoe _et al._, 1960, pp. 1508, 1509) _Eotetragonites_ and _Argonauticeras_ are restricted to the Aptian stage. In western British Columbia, however, _Argonauticeras_? aff. _A. argonautarum_ Anderson (Jeletzky, 1970a, Pl. III, Fig. 6) was found in beds apparently underlying the fine-grained greywacke unit carrying _Heteroceras_ (_Heteroceras_) cf. _helicoceroides_ (Karsten), _Eulytoceras_ spp. and other diagnostic upper Barremian ammonites (Jeletzky and Tipper, 1968, p. 72). Several specimens of _Eotetragonites_ ex gr. _wintunius_ Anderson have been collected in

Manning Park area, B.C. (Jeletzky, 1970b and unpublished intradepartmental fossil reports) in association with such diagnostic Barremian fossils as *Partschiceras infundibulum* (d'Orbigny), *Costidiscus* cf. *striatisulcatus* (d'Orbigny), *Shasticrioceras* cf. *pontiente* Anderson, *Crioceratites* (*Hemihoplites*) n. sp. ex aff. *C.* (*H.*) *soulieri* (Matheron) and *Toxoceratoides?* n. sp. Therefore, and because of a considerable uncertainty concerning the delimitation of the Barremian and Aptian stages throughout Western North America, *Argonauticeras*? and *Eotetragonites* have been included among the Barremian ammonite genera (Table 4).

Aptian Stage

The strong restriction of the Aptian seas in the Canadian Western Cordillera (pp. 40-42 and Fig. 8) and the extreme scarcity of ammonites in the marine Aptian rocks throughout Western and Arctic Canada (Jeletzky, 1964, 1966, 1970b; Jeletzky and Tipper, 1968) strongly reduces the reliability of the conclusions based on their tabulation (Table 5).

Table 5

Aptian Stage	
North Pacific Province	Boreal Province
Total 5 genera	Total 1 genus
Desmoceratid, genus novum *Eotetragonites* *Ammonitoceras*? *Acanthoplites* *Aconeceras*	*Tropaeum*
Common genera - none	

In spite of the extreme scarcity of data available the complete absence of ammonite genera common to the Aptian marine basins of the North Pacific and Boreal Provinces supports the independently reached conclusion (*see* pp. 40-42 and Fig. 8) that the direct marine connection between these basins was interrupted during Aptian time.

It should be noted in this connection that the *Tropaeum* forms (*T. australe*, *T. undatum*, *T.* n. sp. aff. *arcticum*, and *T.* cf. *hillsi*; *see* Jeletzky, 1964 and unpublished intradepartmental fossil reports) are not closely related to *Tropaeum percostatum* (Gabb) diagnostic of the Aptian rocks of northern California (Anderson, 1938, Murphy, 1956). These Canadian *Tropaeum* forms and their Australian and European counterparts (Whitehouse, 1926; Stolley, 1912; Casey, 1960) may well represent an independent lineage of *Tropaeum* s. lato stock deserving a subgeneric separation from *T. percostatum*. The presence of *Tropaeum* in California and in the Canadian Boreal Province cannot, therefore, be used as an argument in favour of a direct connection between these Aptian basins via the marine geosynclinal troughs of western British Columbia and southern Yukon.

The evaluation of the paleogeographic relationships of Aptian ammonite faunas of Western and Arctic Canada is made even more difficult by the already mentioned uncertainty concerning the delimitation of the Barremian and Aptian faunas throughout the western part of North America.

Albian Stage

The Albian ammonite faunas of the North Pacific Province of Canada are adequately known through the posthumous work of McLearn (in press) devoted to the Albian faunas of Queen Charlotte Islands. This work is supplemented by the more recent identifications of the Albian ammonites from the mainland of British Columbia by the writer (Jeletzky and Tipper, 1968 and unpublished intradepartmental fossil reports).

The Albian ammonite faunas of the Boreal Province of Canada are also adequately known (Reeside and Cobban, 1960; Imlay, 1960; Jeletzky, 1964 and unpublished). The following tabulation of Albian ammonite genera is therefore believed to be more nearly complete than that of any other stage.

Table 6

Albian Stage	
North Pacific Province	Boreal Province
Total 29 genera	Total 12 genera
Zelandites	
Turrilites	
Tetragonites	
Puzosia	
Ptychoceras	
Pseudouhligella	
Pseudohelioceras	
Proplacenticeras	
Parasilesites	
Parajaubertella	
Mortoniceras	
Mesopuzosia?	
Marshallites	
Mariella	
Leconteites	
Kossmaticeras	
Hypophylloceras	
Hamitoides	*Sonneratia*
Hamites	*Pseudopulchellia*
Grycia?	*Neogastroplites*
Eogunnarites	*Metengonoceras*
Douvilleiceras	*Grantziceras*
Calliphyloceras	*Gastroplites*
Brewericeras	*Diploceras*
*Arcthoplites**	*Colvillia*
Anisoceras	*Cleoniceras*
Anahoplites	*Beudanticeras*
Anagaudryceras	*Arcthoplites**
Ammonoceratites	*Anadesmoceras*
Common genera (marked by an asterisk) 1	

The extreme scarcity of ammonite genera common to the North Pacific and Boreal Provinces of Canada and the relative depauperation of the Albian Boreal ammonite fauna are, therefore believed to approximate closely the actual state of affairs. It may be pointed out in this connection (compare Fig. 2) that the 29 ammonite genera known from the Albian rocks of the North Pacific Province are distributed among only four zones with the resulting ratio of 7.25 genera per zone. The 12 ammonite genera known from the Boreal Province are, in contrast, distributed among thirteen ammonite zones with the resulting ratio of 0.92 genera per zone. These ratios provide a much better illustration of an extreme depauperation of Albian ammonite faunas of the Boreal Province of Canada as compared with those of its North Pacific Province than the simple tabulation of the Albian genera attempted in Table 6.

As already mentioned, the almost total dissimilarity of Albian ammonite faunas of the North Pacific and Boreal Provinces of Canada reflects the permanent loss of direct marine connections between their marine basins in the wake of the Aptian orogenic movements (*see* p. 40 and Figs. 9, 10). This total dissimilarity may have been furthered by the more or less tenuous nature of such roundabout seaways (e.g. that of the Bering Strait) as must have connected these biotic provinces throughout Albian time.

As stressed by Stelck (1958) and Warren and Stelck (1959, pp. 18, 19), the Canadian Western Interior basin became increasingly strongly isolated from the Canadian Arctic basin during the late middle and late Albian. This circumstance must have strongly favoured the evolution of the endemic gastroplitid faunas in the Canadian Western Interior seas throughout the late middle and late Albian (e.g. *Pseudopulchellia*, *Gastroplites*, and *Neogastroplites* faunas). However, true *Gastroplites* (Warren and Stelck, 1959, p. 15; Imlay, 1961; Jeletzky, 1964; Pergament, 1969) and *Neogastroplites* (unpublished fossil reports of the writer and Pergament, 1969) were recently discovered in the Canadian Arctic basin (Banks Island), in northern Alaska, and in northeastern Siberia, and *Metengonoceras* is known to occur in the *Gastroplites* (Jeletzky, unpublished) and *Neogastroplites* (Jeletzky *in* Thorsteinsson, 1952, p. 28; Reeside and Cobban, 1960, p. 26) zones of the Western Interior of North America. These faunal affinities necessitate the existence of more or less restricted seaways connecting the *Gastroplites* and *Neogastroplites* basins of the Western Interior of Canada with contemporary seas of the Canadian and American Arctic and with the Tethyan seas of the Gulf of Mexico region.

The climatic factor was apparently much less important than that of the land barriers in producing dissimilar Albian ammonite faunas of the North Pacific and Boreal Provinces of Canada. This is indicated by the presence of strongly mixed North Pacific and Boreal ammonite faunas in southeastern Alaska (Imlay, 1960, Jones, 1967) and Soviet Far East (Pergament, 1969). The penetration of *Dipoloceras* and *Metengonoceras* (Stelck *et al.*, 1956, p. 6; Warren and Stelck, unpublished manuscript; Reeside and Cobban, 1960; Jeletzky, unpublished) into the Canadian Western Interior basin following the opening of a direct seaway connecting it with the Mexican Gulf basin in late middle Albian time confirms this idea.

Cenomanian Stage

It is rather difficult to compare the Cenomanian ammonite faunas of the North Pacific and Boreal Provinces of Canada as those of the former province are only known from a few sections on Queen Charlotte Islands (Sutherland Brown, 1968, p. 92; McLearn, in press) and northern Vancouver Island (Jeletzky, 1969, 1970d) and were neither systematically collected nor adequately studied.

So far as known (compare Jones, 1967, p. 4) all Cenomanian ammonites hitherto collected from the Haida Formation of Queen Charlotte Islands (McLearn, in press; Sutherland Brown, 1968, p. 92) appear to form part of a single lower Cenomanian zone designated as *Desmoceras* (*Pseudouhligella*) *japonicum* zone by Jones (1967, p. 4). The *Eogunnarites* cf. *unicus* (Yabe) fauna of Quatsino Sound (Jeletzky, 1970d) is probably equivalent to this zone but the *Eucalycoceras*? ex aff. *E.* ?*shastense* fauna of the northern shore of Vancouver Island (Jeletzky, 1970d) is definitely younger and almost certainly late Cenomanian in age.

Table 7

Cenomanian Stage	
North Pacific Province	Boreal Province
Total 10 genera	Total 10 genera
Turrilites s. str.	*Scaphites*
Tetragonites	*Neogastroplites*
Sciponoceras	*Metasigaloceras*?
Puzosia	*Irenicoceras*
Pseudouhligella	*Forbesiceras*?
Parajaubertella	*Dunveganoceras*
Eucalycoceras?	*Borissiakoceras*
Eogunnarites	*Beattonoceras*
Anisoceras	*Acompsoceras*?
Anagaudryceras	*Acanthoceras*
Common genera - none	

As now known, Cenomanian North Pacific faunas of the Western Cordillera have no common genera with those of the Western Interior Region of Canada. The same appears to be true of the more representative samples of the *D.* (*P.*) *japonicum* fauna described from southeastern Alaska by Matsumoto (1959a, p. 85) and Jones (1967, p. 4). This conclusion is, however, almost certainly not applicable to the North Pacific and Boreal Cenomanian faunas considered as a whole as indicated by the presence of *Calycoceras* and *Acanthoceras* in the mid- to late Cenomanian rocks of southeastern Alaska, Oregon and California (Anderson, 1958, p. 29; Jones, 1967, p. 42). *Calycoceras* sp. is so far only known to occur in the Cenomanian rocks of the Western Interior Region of the United States (Cobban and Reeside, 1952, p. 1023). It should, however, be present also in the little known equivalent mid- to late Cenomanian rocks of the lower Athabasca River area in Canada.

As summarized in Table 7, the Boreal Cenomanian ammonite fauna of Canada is exceptional among the Boreal Cretaceous faunas in seeming to be just as diversified as its North Pacific equivalent. This is, however, an obvious statistical artifact caused by the already mentioned extremely poor state of our knowledge of the latter fauna. The somewhat better (but still rather imperfectly) known Cenomanian ammonite faunas of southeastern Alaska include at least 11 genera (*Anagaudryceras*, *Calycoceras*, *Eogunnarites*, *Marshallites*, *Neophylloceras*, *Parajaubertella*, *Partshiceras*?, *Pseudouhligella*, *Tetragonites*, *Wellmanites*, and *Zelandites*?; *see* Matsumoto, 1959a; Jones, 1967) as against 10 genera known in the Boreal Cenomanian fauna of Canada. The actual disparity between the faunas concerned must be even greater considering the presence of *Acanthoceras* in the North Pacific Cenomanian fauna of California (Anderson, 1958, p. 29), the extreme richness of the North Pacific Cenomanian fauna of Japan (Matsumoto, 1942-43, 1959b), and the circumstance that at least three ammonite genera questionably recorded from the uniquely rich lower Cenomanian Boreal fauna of the Peace River area (Warren and Stelck, 1958 and Table 7) are based on poor shell fragments and may well be discredited in the future.

Even if one allows for the above mentioned deficiencies of data available, the Cenomanian ammonite faunas of the Boreal Province of Canada are unusually diversified, especially if contrasted with the extremely depauperated Boreal Albian ammonite faunas (Table 6). This striking increase of diversity was obviously caused by a marked improvement of marine connections between the Boreal basins of Central and Arctic Canada and Tethyan seas of the Gulf of Mexico Region (Fig. 12). As already mentioned, the direct marine connection between these two groups of basins was first established in late middle Albian (*Gastroplites*) time. However, only a very few Gulf of Mexico ammonites had been able to migrate into the Canadian Western Interior sea prior to the end of Albian time and its ammonite faunas have been dominated by the endemic gastroplitids.

The Cenomanian fauna of the Canadian Western Interior Region (Warren and Stelck, 1956, 1958 and intradepartmental fossil reports of Jeletzky) includes several cosmopolitan genera common to the Tethyan and Boreal Realms the world over (e.g. *Scaphites*, *Borissiakoceras*, *Acanthoceras*, *Acompsoceras*?, *Metasigaloceras*?, *Forbesiceras*?) in addition to the last *Neogastroplites*, other gastroplitid derivatives (*Beattonoceras* and *Irenicoceras*), and endemic acanthoceratids (*Dunveganoceras*). Some of the above mentioned cosmopolitan genera (e.g. *Acompsoceras*?, *Metasigaloceras*?, *Acanthoceras*, etc.; *see* Warren and Stelck, 1958, p. 40; 1959, pp. 18, 19) may be descendants of the gastroplitid stock rather than ancestors of *Lyelliceras*-like mortoniceratids. If so, they migrated into the Gulf of Mexico basins and elsewhere from the Canadian Western Interior sea during early Cenomanian time. Other cosmopolitan genera (e.g. *Scaphites* and *Borissiakoceras*) must have migrated into the Canadian Western Interior basins from the Gulf of Mexico seas via the United States Western Interior seaway. This rather extensive exchange of ammonite fauna between the Boreal basins of the Canadian Western Interior Region and the Tethyan basins of the Gulf of Mexico region first established in the Cenomanian time foreshadows the much more extensive exchange in the Turonian-Coniacian time (*see* below).

Turonian to Lower Santonian Stages

It is impossible to compare the Turonian to middle Santonian ammonite faunas of the North Pacific and Boreal Provinces of Canada as the North Pacific faunas of these times are almost unknown in the Canadian Western Cordillera (Figs. 3, 4) except for the lower Turonian *Inoceramus labiatus* fauna of the upper Haida Formation on Queen Charlotte Islands (Whiteaves, 1884, p. 193; Mackenzie, 1916; Sutherland Brown, 1968, p. 92). This fauna does not include, however, any generically identifiable ammonites.

The Turonian (especially early Turonian) ammonite faunas of the Canadian Western Interior basins are more diversified and at the same time more cosmopolitan than any of the preceding or succeeding Cretaceous faunas. Most of the Turonian ammonite genera, such as *Sciponoceras*, *Metoiceras*, *Watinoceras*, *Prionocyclus* s. lato (including *Collignoniceras* and *Selwynoceras*), *Scaphites*, *Otoscaphites* and *Baculites*, are cosmopolitan or near cosmopolitan in their occurrence. The presence of such a predominantly North Pacific genus as *Otoscaphites* is especially significant. There is, therefore, every reason to expect that most or all of these genera will be found in the upper Haida and/or? Honna Formations of Queen Charlotte Islands when these formations are subjected to more extensive collecting.

The Coniacian and early to middle Santonian ammonite faunas of the Canadian Boreal basins are considerably more provincial and at the same time more depauperated than either the Turonian or lower Campanian ammonite faunas of this province. This is especially well illustrated by the disappearance or rarity of most ammonite stocks other than scaphitids and baculitids, and by the development of several endemic scaphitid subgenera (e.g. *Clioscaphites*, *Desmoscaphites*) out of the cosmopolitan *Scaphites* s. str. stock (Cobban, 1951). These subgenera were only able to migrate northward into the Boreal basins of Western Greenland and northern Siberia (Jeletzky, 1950; Birkelund, 1965) via the seaway extending across the Canadian Arctic Archipelago (Fig. 14). The Canadian Western Interior baculitids remained, on the contrary, closely related to those of the Tethyan seas of the Gulf of Mexico and those of the Boreal seas of the Atlantic seaboard of North America. This suggests that the localization and depauperation of the early to middle Santonian ammonite faunas of the Canadian Western Interior and Arctic basins was caused by deterioration of climatic conditions [the Santonian climatic minimum clearly reflected in the paleogeographical and paleotemperature studies of Russian and Soviet workers (e.g. Arkhangelsky, 1912; Jeletzky, 1948, pp. 593-594; 1958a, pp. 13, 14; Naidin, 1954; Naidin, Teiss, and Chupakhin, 1956, p. 33)], rather than by any restriction of their outside marine connections. As already mentioned, there is every reason to conclude that an extensive marine transgression occurred during Coniacian and early to middle Santonian times following a limited marine regression in late Turonian time.

Upper Santonian

The *Inoceramus naumanni* subzone (including the *Pachydiscus perplicatus* beds) of southeastern Vancouver Island was dated as of the late Santonian age by Jeletzky (*in* Muller and Jeletzky, 1967, p. 43).

The extreme scarcity of late Santonian ammonite genera common to the North Pacific and Boreal Provinces of Canada is well illustrated by the following tabulation:

Table 8

Upper Santonian	
North Pacific Province	Boreal Province
Total 14 genera	Total 5 genera
Ryugasella	
Pseudoxybeloceras	
Polyptychoceras	
Parapuzosia	
Pachydiscus	
Neophylloceras	
Hauericeras	
Gaudryceras	
Epigoniceras	
Diplomoceras	*Placenticeras*
Desmophyllites	*Hoploscaphites*
Damesites	*Desmoscaphites*
Bostrychoceras	*Clioscaphites*
*Baculites**	*Baculites**
Common genera (marked by an asterisk) 1	

The mixed North Pacific and Boreal ammonite and inocerami faunas of Siberia and the Soviet Far East suggest that the *Inoceramus naumanni* subzone is approximately contemporary with the following zones of the Western Interior and Arctic Regions (Jeletzky, 1968a, pp. 40-43).

1. Part or all of *Scaphites* (*Clioscaphites*) *montanensis* zone;
2. Zone I; and
3. *Scaphites* (*Desmoscaphites*) zone.

As shown in Table 8, *Inoceramus naumanni* subzone is known to contain 14 ammonite genera and subgenera as compared with 5 ammonite genera and subgenera occurring in the above mentioned three upper Santonian zones of the Boreal Province of Canada.

In the Boreal Province of Canada *Hoploscaphites* and *Desmoscaphites* are restricted to the latest Santonian zone 3 while *Clioscaphites* is restricted to zones 1 and 2. The actual depauperation ratio of ammonite genera is thus closer to 14:3 than to 14:5 (or 36 per cent) indicated by the simple tabulation of genera attempted in Table 8.

Lower Campanian

As now known (Table 9), the lower Campanian ammonite fauna of the North Pacific Province of Canada has just as few affinities with the strongly depauperated fauna of the Boreal Province as its upper Santonian fauna. In contrast with the upper Santonian, however, there does not seem to be any marked discrepancy between the number of fossil zones distinguishable in the lower Campanian rocks of these two provinces. Only two fossil zones have so far been distinguished in the lower Campanian rocks of either province (Fig. 3). This anomalous equalization of the relative speed of the turnover of the ammonite genera in both provinces concerned may, however, be more

Table 9

Lower Campanian	
North Pacific Province	Boreal Province
Total 15 genera	Total 4 genera
Ryugasella	
Pseudoschloenbachia	
Pseudoxybeloceras	
Pachydiscus	
Neophylloceras	
Hauericeras	
Gaudryceras	
Eupachydiscus	
Epigoniceras	
Diplomoceras	
Desmophyllites	
Damesites	*Placenticeras*
Canadoceras	*Hoploscaphites*
Bostrychoceras	*Haresiceras*
*Baculites**	*Baculites**
Common genera (marked by an asterisk) 1	

apparent than real. Cobban (1964, p. 11, Table 2) was able to distinguish no less than four ammonite zones in the lower Campanian rocks of the Western Interior Region of the United States. There are good reasons to believe that these zones will be found to be equally valid for the Western Interior basin of Canada which represents a direct northward extension of the United States Western Interior sea (Fig. 16).

Upper Campanian

Tabulation of the upper Campanian ammonite faunas of the North Pacific and Boreal provinces of Canada (Table 10) seems to indicate their somewhat closer affinity as compared to the upper Santonian and lower Campanian faunas but these faunas are actually somewhat more dissimilar (compare Tables 9, 11) than either the lower Campanian or the early lower Maestrichtian faunas of these provinces. However, the upper Campanian baculites of the Canadian North Pacific Province (*Baculites* ex gr. *chicoensis* sensu Usher, 1952 = *?Baculites inornatus* Meek sensu Matsumoto 1959 and *Baculites occidentalis* Meek) are much less closely related to their Boreal counterparts (*Baculites* ex gr. *compressus* Say s. lato) than are either the upper Santonian and lower Campanian or the early Maestrichtian baculite species. Therefore the statistical presence of the genus *Baculites* in the upper Campanian rocks of the North Pacific and Boreal provinces of Canada has little real meaning. The same is true of the statistical presence of morphologically dissimilar and only doubtfully congeneric species of *Didymoceras*, such as *D. cheyennense* Meek and Hayden in the upper Campanian of the Western Interior Region (Riding Mountain Formation of Manitoba; Jeletzky, unpublished) and *D.? cooperi* Gabb in the late upper Campanian of Vancouver Island (Usher, 1952).

Table 10

Upper Campanian	
North Pacific Province	Boreal Province
Total 17 genera	Total 6 genera
Ryugasella	
Pseudoschloenbachia	
Pseudophyllites	
Pseudoxybeloceras	
Patagiosites	
Pachydiscus	
Neophylloceras	
Metaplacenticeras	
Hoplitoplacenticeras	
Gaudryceras	
Epigonoceras	
Diplomoceras	*Rhaeboceras*
*Didymoceras**	*Ponteixites*
Desmophyllites	*Placenticeras*
Canadoceras	*Hoploscaphites*
*Baculites**	*Didymoceras**
Anapachydiscus	*Baculites**
Common genera (marked by an asterisk) 2	

The degree of depauperation of the upper Campanian ammonite fauna of the Canadian part of North American Boreal Province (Table 10) is comparable to that of its upper Santonian and lower Campanian faunas (Tables 8, 9).

The discrepency between the number of fossil zones distinguishable in the upper Campanian rocks of the North Pacific and Boreal Provinces of Canada (Fig. 3) appears to be less marked than that characteristic of upper Santonian time. The number of well-defined fossil zones distinguishable in the upper Campanian rocks of Western Interior basin of Canada is, however, considerably greater than that indicated in Fig. 3. Most or all of twelve ammonite zones recognized in the Western Interior Region of the United States by Scott and Cobban (1965) will undoubtedly be found equally well applicable to the Canadian part of the Western Interior Region as soon as its baculitid, scaphitid, and normal ammonites are restudied. Therefore, the considerably faster turnover rate of ammonite genera characteristic of the Boreal Province in Albian and Santonian times appears to be equally characteristic of Upper Campanian time.

Early Lower Maestrichtian

Except for the already mentioned closer affinity of their *Baculites* species, the early lower Maestrichtian ammonite faunas of the North Pacific and Boreal Provinces of Canada are just as dissimilar as are the upper Santonian and Campanian faunas of these provinces (Table 11). The North Pacific fauna continues to be much more diversified than that of the Boreal Province though its depauperation appears to be considerably less marked (43 per cent) than that of the late Santonian and Campanian faunas. It is not possible to compare the rapidity of a turnover of the Maestrichtian ammonite genera in the North Pacific and Boreal Provinces as it is unknown whether or not the *Nostoceras hornbyense* subzone of Vancouver Island corresponds to both Maestrichtian zones of the Western Interior Region of Canada or just to the lower of these two zones (Fig. 3).

Table 11

Early Lower Maestrichtian	
North Pacific Province	Boreal Province
Total 7 genera	Total 3 genera
Pseudophyllites *Partschiceras* *Pachydiscus* *Nostoceras* *Neophylloceras* *Didymoceras* *Baculites**	*Hoploscaphites* *Discoscaphites* *Baculites**
Common genera (marked by an asterisk) 1	

Rates of Generic Turnover in North Pacific and Boreal Provinces

The foregoing tabulation and discussion of the ammonite faunas of the individual stages of the North Pacific and Boreal Provinces of Canada reveals an interesting regularity of turnover rates of the ammonite genera.

The comparison of the number of fossil zones distinguishable within the individual Cretaceous stages and substages in the North Pacific Province with that distinguishable within their counterparts in the Boreal Province (Figs. 2, 3) indicates that an about equal to closely comparable number of fossil zones is distinguishable in the Berriasian to Barremian stages of these two provinces. The existing discrepancies, such as the greater number of fossil zones distinguishable in the Valanginian and Barremian stages of the Boreal Province as compared with their North Pacific counterparts is probably more apparent than real and caused by the less satisfactory state of knowledge of the North Pacific ammonite faunas concerned.

No valid zonal comparison is possible for the Aptian stage but a marked change ensued in the Albian stage. Only four ammonite zones can be distinguished in the complete and relatively well-known (McLearn, in press; Jeletzky, unpublished) Albian sequence of the North Pacific Province as compared with the minimum of thirteen ammonite zones in the about equally complete and relatively well-known Albian sequence of the Boreal Province (Fig. 2). Thereafter, the same zonal relationships (i.e. ratios of zones) prevail in all Upper Cretaceous stages and substages in which the ammonite faunas are sufficiently well known to permit a meaningful comparison (e.g. upper Santonian, lower Campanian and upper Campanian; *see* Fig. 3 and the corresponding sections of this chapter). There are good reasons to believe that the same relationships are also prevalent in those stages (Cenomanian, Turonian, Coniacian, and lower to middle Santonian) where a meaningful comparison of zones per equivalent North Pacific and Boreal stages is still impossible.

The considerably slower turnover of ammonite genera in the Albian and mid- to late Upper Cretaceous rocks of the Canadian North Pacific Province compared with those of the Boreal Province is obviously related to the almost complete isolation of these provinces from each other following the Aptian orogeny. It seems likely that the ensuing considerably more favourable and more diversified environments (higher water temperature, greater diversity of facies etc.) of the North Pacific Province lowered the selection pressure there. This must have favoured the survival of well-established ammonite genera alongside the succeeding genera (evolutionary descendants) or new arrivals. The evolution of Albian and Upper Cretaceous ammonite faunas in the North Pacific Province of Canada apparently was more strongly influenced by the addition of new genera than by the extinction of the old genera. One cannot escape an impression that it had become a faunal refuge of sorts. Judging by the data available in the Japanese, Indian, Soviet and New Zealand literature these conclusions are valid for the Albian and Upper Cretaceous ammonite faunas of at least the North Pacific and Indo-Pacific Provinces of the Tethyan Realm (Matsumoto, 1942-43, 1959b; Pergament, 1969, Table 2).

The considerably harsher living conditions which arose in post-Aptian time in the Boreal Province of Canada (e.g. lower water temperature and less diversified facies) apparently exerted a considerably greater selection pressure on the depauperated Albian and Upper Cretaceous ammonite faunas. This selection pressure and the limited choice of available biotopes must have favoured a faster extinction of older ammonite genera and a faster spread of the succeeding genera (evolutionary descendants) or new arrivals throughout the basins concerned. There does not seem to be any other convincing explanation for the above mentioned, considerably faster turnover of Albian and Upper Cretaceous ammonite genera of the Boreal Province of Canada and the much better delimitation of the successive ammonite faunas there.

The above discussed biochronological and evolutionary relationships of the Boreal and North Pacific ammonite faunas of Western and Arctic Canada are incompatible with the simple, quantitative (more or less linear) relationships supposed to exist between the latitudinal gradients of taxonomic diversity and rates of evolutions (Stehli, Douglas and Newell, 1969). Contrary to this speculation the evolutionary rates of the ammonite faunas concerned, as expressed by the turnover of ammonite genera (Figs. 2-4), either appear to be unaffected by the pronounced latitudinal gradients of taxonomic diversity (i.e. in the Berriasian to Barremian) or exhibit regularities diametrically opposed to those demanded by it (i.e. in the Albian and Upper Cretaceous). The same appears, furthermore, to be true of other biochronologically important fossil groups (e.g. Belemnitida, Buchiidae, Inoceramidae), although a detailed analysis of the behavior of these groups is beyond the scope of this paper.

The considerably faster turnover of genera in strongly depauperated Albian and Upper Cretaceous ammonite faunas of colder Boreal seas of Western and Arctic Canada (Figs. 2-4) also contradicts the extremely far-reaching biochronological generalizations (Stehli, Douglas and Newell, 1969, p. 949) based solely on the alleged existence of universally valid simple relationships between the latitudinal gradients of taxonomic diversity and evolutionary rates. These biochronological generalizations conflict equally strongly with the bulk of paleogeographical, evolutionary and biochronological data obtained by the writer during his studies of the Cretaceous and Jurassic marine invertebrates (e.g. latest Jurassic ammonites, Belemnitida, Teuthida, Inoceramidae, Buchiidae) of Northern Europe and Canada. These data will be presented later in a publication devoted to the most important but extremely complex problem of generation and maintenance of gradients in taxonomic diversity and its biochronological implications.

PALEOGEOGRAPHICAL IMPLICATIONS

An historical analysis of paleobiotic data is critical for a correct paleogeographical evaluation of detailed but often highly ambiguous data provided by areal distribution and the facies changes of well-dated marine and nonmarine rocks (Schuchert, 1910, pp. 437-447; 1923). This powerful paleogeographical tool is particularly important for the restoration of the areal extent of the individual marine basins the sedimentary record of which is partly or largely destroyed and for the deduction of the presence or absence of direct and easy marine connections between such basins. The following chapter is an attempt to utilize paleobiotic data in the reconstruction of the evolution of gross features of the Cretaceous land and sea patterns in Western and Arctic Canada.

An historical approach is used throughout, the data available being organized under the heading of international stages and substages. For reasons presented in the section dealing with the comparison of the North Pacific and Boreal ammonite faunas, it was not feasible to differentiate strictly between the events referable to the individual fossil zones within every stage or substage. Attempts were made, however, to draw the accompanying paleogeographical maps (Figs. 5-20) to present paleogeographical conditions pertaining either to a single fossil zone or to several adjacent fossil zones wherever the requisite data were available.

Sixteen paleogeographical maps (Figs. 5-20) show the inferred successive land and sea patterns in Western and Arctic Canada during the individual Cretaceous stages and substages. The small scale of these maps reflects the stress on the restoration of the basic paleogeographical features and a conscious effort to portray either the maximum or the minimum extents of the individual Cretaceous seas. A detailed mapping of the margins of successive Cretaceous seas is beyond the scope of this study. For this reason, no attempt was made to indicate the individual lithofacies on any of the maps.

The writer is acutely conscious of the scant and often tenuous nature of evidence on which his paleogeographical reconstructions are based. As aptly pointed out by McLearn (1944, p. 2): "Like all palaeogeographical maps, they involve much speculation. They are what the evidence now on hand justifies and nothing more. Like all previous maps they are subject to revision and addition as new facts are collected. It is thought, however, that

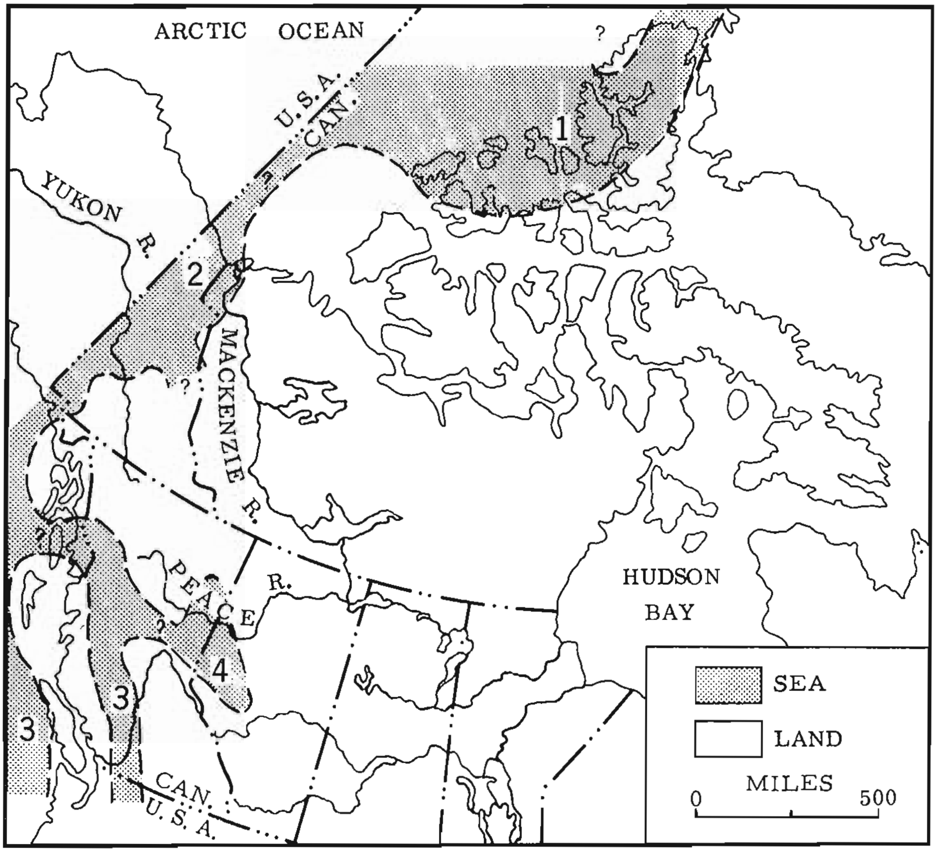


Figure 5. Berriasian paleogeography. The map shows the inferred maximum extent of Berriasian seas. See below for explanation of numerical symbols of this figure.

very definite progress is being made and that each generation of maps comes nearer to the truth. Moreover, it seems advisable to issue these revised maps from time to time because they focus attention on unsolved problems of correlation and sedimentation and so stimulate investigation."

Berriasian

The inferred distribution of land and sea in earliest Cretaceous or Berriasian time is shown in Figure 5. The fossiliferous marine Berriasian rocks appear to be confined to the following depositional basins of Western and Arctic Canada indicated by corresponding numbers on the paleogeographical map concerned:

1. Sverdrup Basin in the Canadian Arctic Archipelago;
2. intracratonic trough of Richardson and Barn Mountains in northern Yukon and Mackenzie District and the marine basin of adjacent parts of Porcupine-Eagle Plains;
3. two residual geosynclinal troughs of the Canadian Western Cordillera; and
4. depositional basin of Peace River Foothills and Plains in northeastern British Columbia and northwestern Alberta.

The Sverdrup and Richardson Mountains-Porcupine Plain basins are characterized by the almost identical North American Boreal faunas and obviously were directly connected on a wide front beneath the present Beaufort Sea.

The Peace River Basin was long considered to be an arm of the Boreal seas (e.g. McLearn, 1944, p. 5, Fig. 1; McLearn and Kindle, 1950, p. 130; Rudkin, 1964, p. 158, Fig. 11; Ziegler, 1969, p. 24). This conclusion was, however, discredited by Warren and Stelck's (1956, 1958, 1961, unpublished manuscript) discovery of North Pacific affinities of the upper Tithonian and Berriasian marine faunas of the Peace River Basin. A more detailed study of Jeletzky (1964, 1968a), Jeletzky and Tipper (1968, p. 83) and Jeletzky (1970a, c) has fully confirmed Warren and Stelck's (ibid.) findings. The presence of a long lasting and easy marine connection between the early Lower Cretaceous Tyaughton Trough and the Peace River Basin on the one hand and between the Tyaughton, Insular (= Vancouver Island-Queen Charlotte Islands Trough of Jeletzky and Tipper; 1968, pp. 5, 74) and Washington-Oregon troughs on the other was inferred by Jeletzky and Tipper (1968, p. 83) because of extremely close affinities of the invertebrate faunas of all these marine basins. The seaway connecting the Tyaughton Trough with the Peace River Basin was named Vanderhoof Strait by Jeletzky (1970a, c). This seaway presumably extended across present Central Plateaux Belt from the headwaters of Skeena River through Vanderhoof area, and into Carbon Creek Basin.

The existence of an alternative seaway extending from the Kluane Lake map-area eastward to and southeastward across the Whitehorse map-area and then farther southeastward across the present day Cassiar Welt appears to be effectively ruled out by Wheeler's (1961, pp. 114, 115) mapping of the Whitehorse map-area. This work indicates a complete emergence of the Whitehorse Trough by the middle or? late Jurassic and its remaining above sea level in the early Cretaceous.

The early to mid-Lower Cretaceous seas of adjacent parts of the Dawson City Seaway apparently did not penetrate east of Shakwak Trench of Kluane Lake and Dezadeash map-areas (*compare* Kindle, 1953; Muller, 1967).

The already mentioned, considerable admixture of the North American Boreal forms in the Berriasian basins of Canadian Western Cordillera and in the Peace River Basin clearly indicates the presence of an easy marine connection between the geosynclinal troughs of the Western Cordillera and the Richardson Mountain-Porcupine Plain Basin. The approximate location of this seaway, named Dawson City Strait by Jeletzky (1970a, c), is indicated by the presence of large outcrop-areas of fossiliferous, predominantly argillaceous, marine upper Tithonian, Berriasian, and Valanginian rocks in Kluane Lake-St. Elias Range area (Kindle, 1953; Muller, 1967) and by that of the presumably late Upper Jurassic to early Lower Cretaceous, mildly metamorphosed sedimentary rocks in Mayo area of southern Yukon (Tempelman-Kluit, 1965; 1966, pp. 48, 49). The latter, apparently marine rocks, are lithologically similar to the upper Tithonian and Berriasian-Valanginian rocks of the Richardson Mountain-Porcupine Plain Basin described by Jeletzky (1958b, 1960, 1961a). However, they did not yield any diagnostic fossils.

The Dawson City Strait must have been in existence throughout Tithonian and Berriasian time because of a virtual identity of all latest Jurassic and earliest Cretaceous *Buchia* faunas of the North American Boreal and North Pacific Provinces (Jeletzky, 1970c).

The Berriasian physiography of Western and Arctic Canada was obviously quite unlike the modern one. The imposing barrier of the present Coast Mountains was only dimly foreshadowed by a large, probably cordillera-like island astride the International Boundary. A narrow but deep Tyaughton Trough (Jeletzky and Tipper, 1968, p. 5; Jeletzky, 1970a) separated this island from the Central Plateaux Belt. Two sublatitudinal seaways connected Tyaughton Trough with the Insular Trough (this name is substituted for the much longer, unwieldy name Vancouver Island-Queen Charlotte Islands Trough proposed by Jeletzky and Tipper, 1968, p. 75).

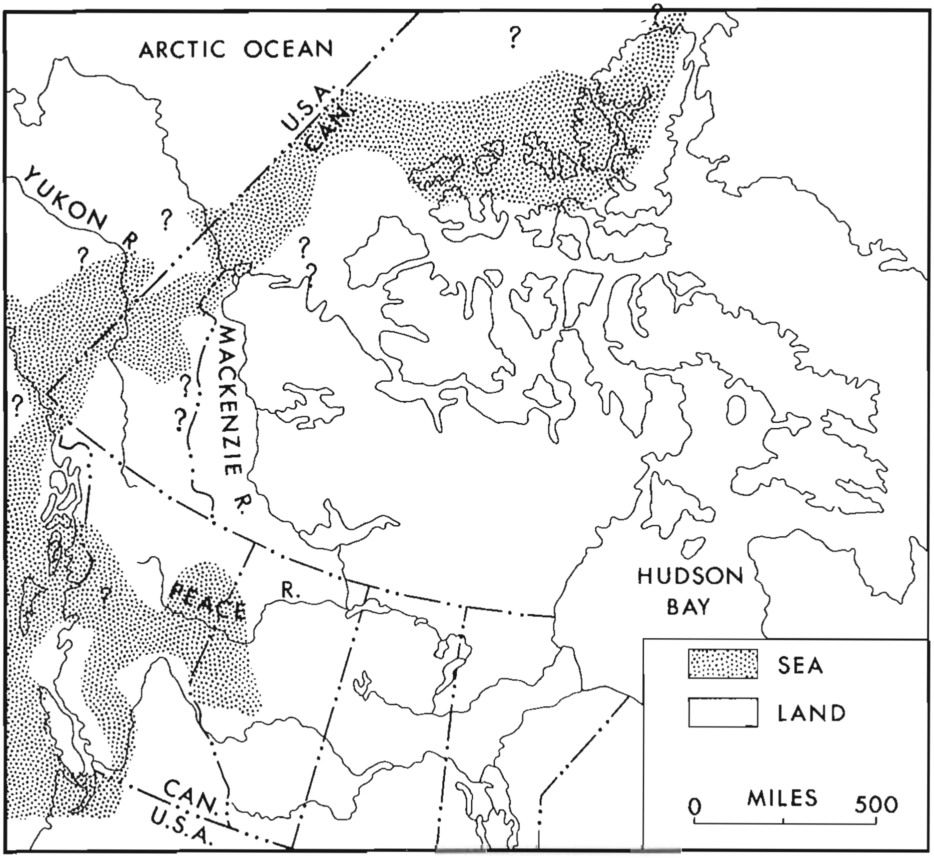


Figure 6. Mid- to late Valanginian paleogeography (*Buchia pacifica* time and early part of *Buchia crassicollis* time combined in the North Pacific basins and *Buchia keyserlingi-Buchia inflata* time in the North American Boreal basins). The map shows the inferred maximum extent of mid- to late Valanginian seas.

The Central Plateaux Belt of central British Columbia was cleaved by the presumably fairly narrow Vanderhoof Strait into the Nelson Welt in the south and Omineca-Cassiar Welt in the north. The North Pacific sea extended deep into what is now the Western Interior Region of Canada between these presumably cordillera-like landmasses. The Rocky Mountains obviously did not exist at all.

In the northwest the even more imposing mountainous barriers of St. Elias, Kluane, and Ogilvie Mountains and the intervening high Klondike Plateau did not yet exist. Their place was occupied by another wide arm of the North Pacific sea - the Dawson City Strait (Fig. 5). This seaway limited the Omineca-Cassiar Welt in the northwest.

The Berriasian Dawson City Seaway apparently opened into southeastern Alaska and into the Kandik area but the extent of the Berriasian sea there is uncertain.

Valanginian

The above described earliest Cretaceous physiography of Western and Arctic Canada persisted essentially unchanged into the Valanginian (Fig. 6) as attested to by the essentially similar distribution of the Berriasian and Valanginian marine rocks and by the far-reaching commingling of the Boreal and North Pacific faunas in the Valanginian (*see* p. 20 and Fig. 4). The only significant change was the flooding of San Juan Archipelago, northwestern end of Vancouver Island, most or all of Queen Charlotte Islands, and considerable parts of Chilko Lake area in the Coast Mountains by the Valanginian sea (Jeletzky and Tipper, 1968, p. 83, Fig. 8; Jeletzky, 1968b, p. 103). This mostly late Valanginian transgression reduced considerably the area of the earliest Cretaceous nucleus of the Coast Mountains (Figs. 5, 6).

So far as known, the North Pacific Peace River Basin and the Boreal Valanginian basins of the Arctic Mainland and the Sverdrup Basin were not affected at all by this late Valanginian transgression. Instead, these basins became definitely regressive toward the end of Valanginian time as attested to by the replacement of finer grained, mostly or entirely marine mid-Valanginian clastics, by mostly coarser grained, partly or entirely nonmarine latest Valanginian and early Hauterivian clastics (Stott, 1967a, pp. 39, 40; Jeletzky, 1958b, 1960, 1961a; Tozer and Thorsteinsson, 1964, pp. 146, 147, 215). This opposition of the direction of tectonic movements in the Western Cordilleran Geosynclinal Belt and outside of it in the sedimentary basins of Western Canada appears to be a significant and rather persistent feature of the Lower Cretaceous paleogeography as it shall be shown in the following sections.

Hauterivian and Barremian

The inferred maximum extent and configuration of the Hauterivian and Barremian seas are shown in Figure 7. The most characteristic feature of this time interval is an apparently complete exclusion of the Hauterivian and Barremian seas from the Peace River Basin, the Vanderhoof Strait and Sverdrup Basin following the latest Valanginian uplift of these nongeosynclinal structural elements.

Jeletzky and Tipper (1968, p. 84) accepted Warren and Stelck's (1961, p. 52, Fig. 8; unpublished manuscript) conclusion about the absence of any elevated land barriers between the Western Interior and Western Cordilleran depositional basins in the Hauterivian-Barremian time and suggested the occurrence of minor temporary ingressions of the Hauterivian and/or Barremian geosynclinal seas into the Peace River Basin. The validity of this suggestion became strongly suspect in the light of a recent re-evaluation of the flora, ostracod fauna, and stratigraphic position of the Lower Blairmore, Gething, and Bluesky (= Home Sand of Warren and Stelck, unpublished manuscript) formations by Stott (1968, pp. 11-14, 40). It now seems more likely that the elevated land barriers between the Peace River Basin and the geosynclinal troughs of the Western Cordillera had already come into being in early Hauterivian time and that Hauterivian-Barremian time is only represented in the Peace River Basin by a regional hiatus between the late Tithonian to late Valanginian Minnes Group (= marine Bullhead of the earlier workers) and the Aptian(?) Cadomin conglomerate.

Unlike other nongeosynclinal basins, the Richardson Mountain-Porcupine Plain Basin was only partly drained at the onset of the Hauterivian (*Homolsomites oregonensis* and *Homolsomites packardi* time), was flooded again in the mid- to late Hauterivian (*Simbirskites kleini* and *Craspedodiscus discofalcatus* time; Jeletzky, 1960, p. 13 and unpublished), and remained below sea level throughout the Barremian (Jeletzky, 1958b; 1960; 1961a; 1964, Table 1; 1968a).

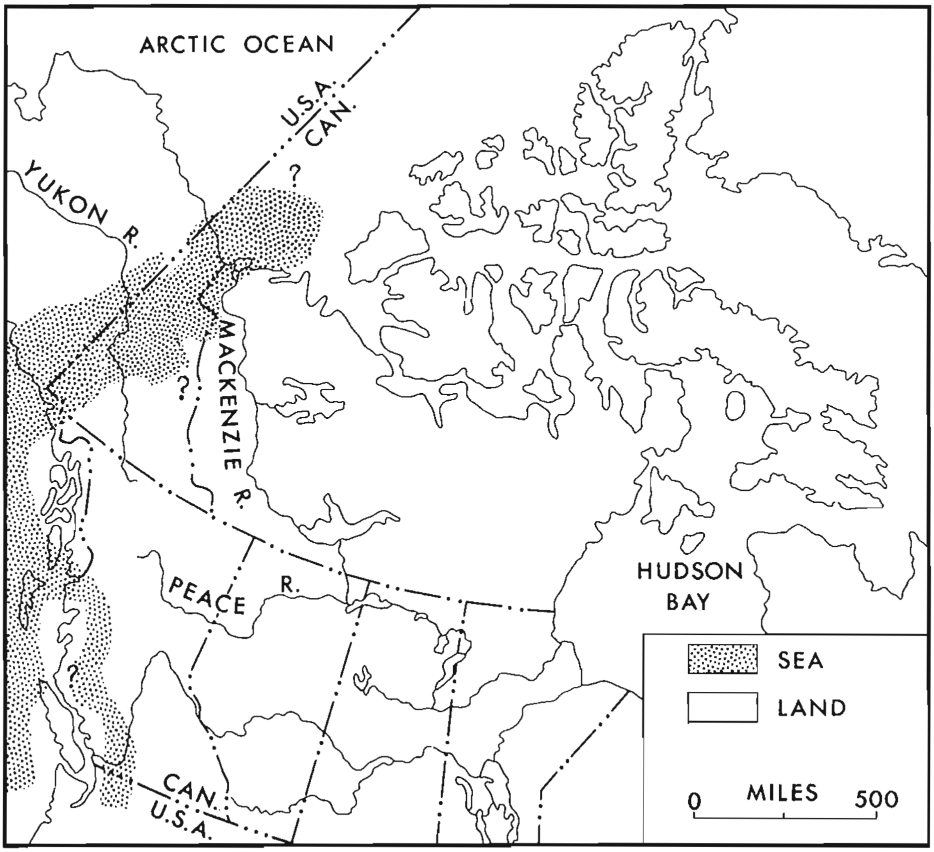


Figure 7. Hauterivian and Barremian paleogeography showing the inferred maximum extent of Hauterivian and Barremian seas (mostly of the late Barremian seas).

In contrast to nongeosynclinal parts of Western and Arctic Canada, Hauterivian and Barremian seas were strongly transgressive in most or(?) all of the Canadian Western Cordillera. On the eastern side of Tyaughton Trough in the Manning Park area of the southern Cascade Mountains these seas covered, for the first time, all of the Skagit River basin and the headwaters of Similkameen River (Jeletzky, 1970b). Furthermore, it seems likely, that the Hauterivian-Barremian seas were similarly transgressive farther north along the eastern side of Fraser River, between Hope and Pavillion at least.

On the west side of Tyaughton Trough the Hauterivian and(?) Barremian seas advanced for a considerable distance west and southwest of Tatlayoko and Chilko Lakes into the parts of the Coast Mountains never before flooded by the Cretaceous seas (Jeletzky, 1968b, p. 105; Tipper, 1969, pp. 55, 56). It seems likely that these seas were similarly transgressive in the westward direction everywhere between Chilko Lake and the International Boundary.

On the eastern flank of the Insular Trough the Hauterivian-Barremian seas were strongly transgressive on the northwestern part of Vancouver Island (Jeletzky, unpublished). There the marine Hauterivian-Barremian rocks (Jeletzky and Tipper, 1968, pp. 71, 72, Table 4) overstepped onto the early

Mesozoic rocks of the Vancouver Group and almost reach the eastern coast of the island. The Barremian rocks strongly overstepped the Hauterivian rocks.

The facies patterns of the Valanginian-Barremian rocks described by Sutherland Brown (1968) on Queen Charlotte Islands suggest that the Hauterivian-Barremian rocks of that area overstepped the late Valanginian (*Buchia crassicollis* zone) rocks in the southeasterly direction.

The complete lack of Berriasian-Valanginian marine fossils and the apparent presence of nonmarine, plant-bearing rocks beneath the Hauterivian-Barremian marine rocks throughout Bowser Basin (unpublished intradepartmental fossil reports of Jeletzky) suggest an extensive Hauterivian-Barremian transgression in northwestern part of British Columbia.

So far as known, the Barremian rocks overstepped the Hauterivian rocks all around the margins of the residual geosynclinal (= eugeosynclinal; Jeletzky, 1963, pp. 58-61) troughs of western British Columbia.

The Neocomian Paleogeographical Phase

As already mentioned, the differences of the Berriasian to Barremian North Pacific faunas from their Boreal counterparts are strongly tempered by the presence of a number of common species and genera. This is well illustrated by the zonal sequences of these provinces (Fig. 2). A number of the Berriasian to Barremian fossil zones of the North Pacific and North American Boreal Biotic Provinces are indeed characterized by generically or even specifically identical index fossils. Another good illustration is provided by the graph of Figure 4 tabulating the numbers of ammonite genera common to the North Pacific and Boreal Provinces of Canada in various Cretaceous epochs. Not only are the Valanginian to Barremian ammonite faunas of these provinces characterized by the greatest ratios of common genera but these ratios increase from the Berriasian to the Barremian when they reach their Cretaceous peak only to drop to zero in the Aptian.

The close affinities of the North Pacific and Boreal invertebrate faunas of Canada from the Berriasian through the Barremian indicate the uninterrupted existence of the Dawson City Strait during this time interval (Figs. 5-7). The gradual increase of these faunal affinities in Berriasian to Barremian time suggests a gradual widening of this seaway during this time interval paralleling the previously described regional Valanginian-Barremian transgression of the geosynclinal seas of the Canadian Western Cordillera. The gradual widening of the Dawson City Seaway was obviously not terminated by the previously mentioned early Hauterivian regression in the Richardson Mountain-Porcupine Plain Basin, even though its progress may have been briefly interrupted by this regression.

The maintenance of an easy marine connection between the North Pacific and Boreal seas of Canada is the most characteristic paleobiotic and paleogeographical feature of the Berriasian-Barremian time interval. It permits the recognition of a distinctive Neocomian phase of the paleobiotic and paleogeographical history of Western and Arctic Canada.

Aptian

The inferred maximum extent and configuration of the Aptian land and sea is shown in Figure 8. The general paleogeographical pattern has changed rather drastically as compared with that characteristic of the Berriasian to Barremian paleogeographic phase (compare Figs. 5-7).

The most important single biotic distinction of the Aptian time consists in the already mentioned (p. 24 and Fig. 4) almost complete dissimilarity of the invertebrate faunas of the North Pacific and Boreal seas of Western and Arctic Canada. In strong contrast to the Barremian faunas, the Aptian

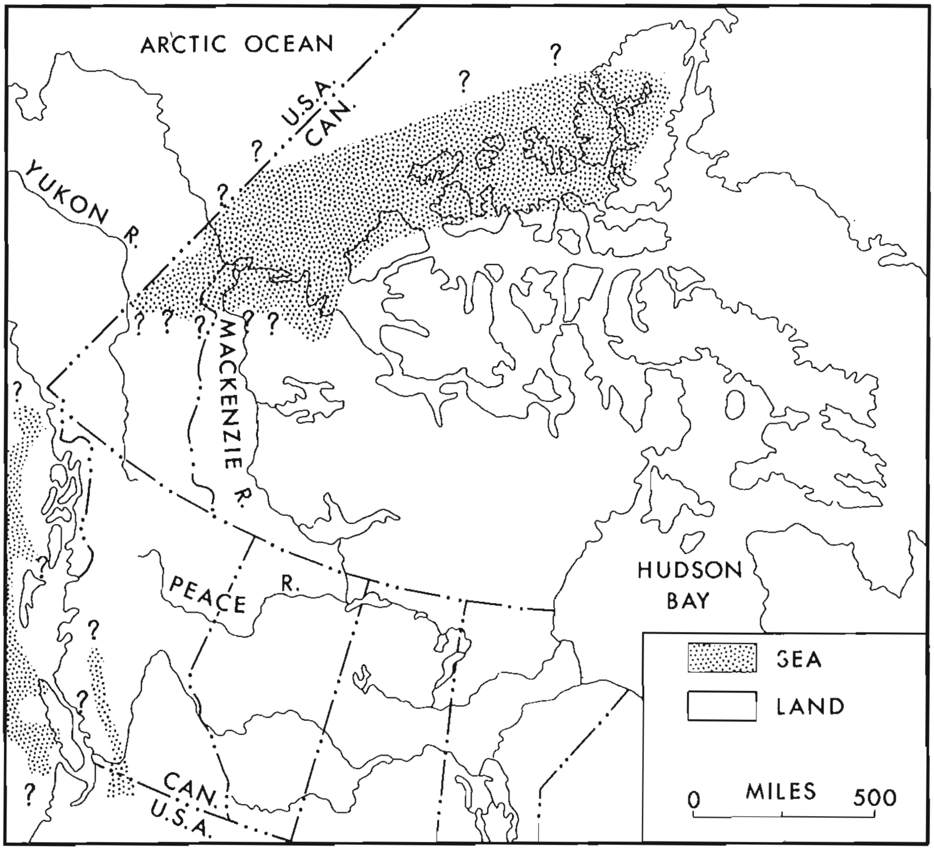


Figure 8. Aptian paleogeography showing the inferred maximum extent of Aptian seas.

North Pacific fauna of western British Columbia does not contain any ammonite genera (let alone species) in common with the Aptian Boreal fauna of the Richardson Mountain-Porcupine Plain Basin. This cardinal paleobiotic change obviously reflects a complete isolation of the North Pacific marine troughs of western British Columbia from the North American Boreal marine basins of the Canadian Arctic resulting from the closure of the Dawson City Strait by the regional Aptian tectonic movements (Jeletzky and Tipper, 1968, pp. 88, 89). This isolation of North Pacific and Boreal seas of Western and Arctic Canada makes the Aptian time an important turning point in the biotic, paleogeographical, and structural history of this region as this isolation persisted through the Albian and Upper Cretaceous times and is still in force today.

The permanent closure of the Dawson City Strait was accompanied by a considerable regression of the geosynclinal Aptian seas throughout the western part of British Columbia. Thick conglomerate units (Jackass Mountain Group and its equivalents) are widespread in marine and nonmarine Aptian rocks of this region (Jeletzky, 1961b, p. 543; Jeletzky and Tipper, 1968, pp. 84, 86, 88, 89) indicating that most or all of the land barriers erected there by the Aptian tectonic movements were mountainous in character. These movements must have caused the emergence of the Central Plateaux Belt in the shape of a cordillera-like tectonic land extending right across central British Columbia and southern Yukon and into southern Alaska. This tectonic land, which can be referred to as the combined Nelson-Omineca Uplift (Jeletzky and Tipper, 1968, p. 88) spread right across the area occupied by the Dawson City Strait in the Barremian.

In contrast to the strongly regressive behaviour of the geosynclinal Aptian seas of the Western Cordillera, their nongeosynclinal counterparts in the Porcupine Plains and Richardson Mountains were almost to quite as widespread as the Barremian seas of the same region (Jeletzky, 1961b, p. 543). The strong Aptian tectonic movements, which obviously occurred in this region, apparently only affected the southern and southeastern margins of the Richardson Mountain-Porcupine River Basin adjoining the northern outlet of the Dawson City Strait and only briefly interrupted the spread of the Aptian transgression there. The latter continued well into late Aptian time in the southern Richardson Mountains as indicated by the fine sandy to silty character of the *Tropaeum australe* beds (= *Parahoplites nutfieldensis* zone) overlying the earlier Aptian conglomerates in Stony Creek-Vittrekwa River area (Jeletzky, 1960, p. 16; 1961b, pp. 539, 540). This interpretation agrees well with the fact that no traces of Aptian tectonic movements were observed anywhere within the Canadian Arctic Archipelago. In this region the fine-grained Aptian to Albian clastics of the Christopher Formation appear to overlie the nonmarine Isachsen Formation conformably and almost gradationally (Souther, *in* Fortier *et al.*, 1963, p. 454; Fricker, 1963, p. 95). Nor is there any evidence of an erosional disconformity or an unconformity within the Christopher Formation, although the presence of a sandstone member in its middle part (Tozer and Thorsteinsson, 1964, p. 156) may be a reflection of the Aptian tectonic movements.

Elsewhere in Arctic Canada the Boreal Aptian seas were strongly transgressive. East of Mackenzie Delta they appear to overlap the Paleozoic rocks at least as far as Darnley Bay area (Jeletzky, 1958b, p. 16; 1960, p. 17, corr. chart). Farther north the Aptian seas apparently flooded most of the Sverdrup Basin (Jeletzky, 1960, p. 17 and in Thorsteinsson and Tozer, 1962, pp. 62-65 and Tozer and Thorsteinsson, 1964, pp. 154, 161) and, judging by the affinities of their ammonite fauna, restored a direct connection between the northern Yukon Basin and the basins of the European Arctic.

Albian

The general configuration of the Aptian land and sea (Fig. 8) is similar to that of the early lower Albian for which no paleogeographical map was drawn. However, unlike the Aptian seas which were apparently restricted to a narrow strip of the Arctic Plain between the Mackenzie Delta and Darnley Bay area and did not extend inland beyond the lower Peel River area, the early lower Albian seas (*Sonneratia* cf. *kitchini* to *Arcthoplites irenense* time; *see* Fig. 2) gradually penetrated deep into the Western Interior Region of Canada via Mackenzie River Basin (Stelck *et al.*, 1956, pp. 6, 8, Fig. 2). The great Albian to mid-Santonian marine invasion of the Great Plains and Rocky Mountain region of Canada via Mackenzie River Basin thus apparently started only in the early lower Albian (*Sonneratia* cf. *kitchini* time).

The North Pacific early lower Albian seas (*Leconteites lecontei* time) apparently were more or less transgressive in most or(?) all of the Canadian Western Cordillera.

Within the Insular Trough in Queen Charlotte Islands the Haida Formation includes *Leconteites lecontei* beds at least at Beresford Bay (Sutherland Brown, 1968, p. 93). This contrasts with the Aptian when the whole area was apparently elevated above sea level and was undergoing erosion (Jeletzky and Tipper, 1968, pp. 73, 74).

On the eastern flank of Tyaughton Trough in the Manning Park area of southern Cascades the argillaceous early lower Albian rocks are obviously

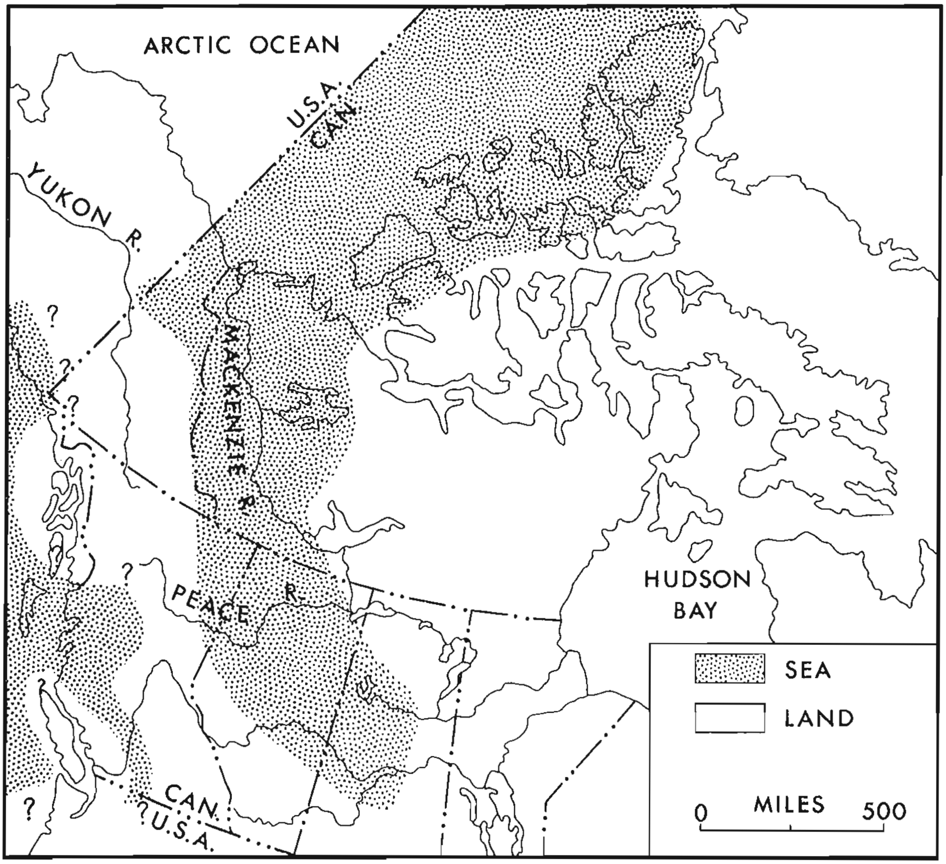


Figure 9. Late lower Albian paleogeography (Clearwater sea or *Arcthoplites mcconnelli* and *Arcthoplites irenense* times combined in the North American Boreal basins and *Brewericeras hulenense* time in the North Pacific basins). The map shows the inferred maximum extent of late lower Albian seas.

transgressive eastward (Jeletzky, 1970b). The same is probably true of the Taseko Lakes and Mount Waddington map-areas on the western side of Tyaughton Trough, judging by the upward replacement of the Aptian conglomerates of the Taylor Creek Group by predominantly argillaceous Albian rocks (Jeletzky and Tipper, 1968, pp. 54-59; Tipper, 1969, pp. 60-65). A *Leconteites lecontei* fauna was subsequently found in some of these Albian sections (Jeletzky, 1968b, p. 104).

The early Albian marine rocks are widespread in the northern part of the Canadian Western Interior Region confined between the Peace River Foothills and Plains and the Arctic Coast (McLearn and Kindle, 1950; Stott, 1960; Jeletzky, 1958b, 1960, 1961a, 1968a; Hume, 1954; Mountjoy, 1967). This suggests an equally extensive early Albian flooding of this region.

In the western part of this vast region the early Albian sea apparently covered all of the Arctic Red and Peel River drainage area, most or all of the Richardson Mountains, and most or all of the Porcupine and Eagle Plains, Its southern shore probably was situated on the northern slopes of the present Wernecke and Ogilvie Mountains (Fig. 9).

In spite of the scarcity of paleontological data, it is assumed that most of this area was flooded already in the early lower Albian (i.e. *Sonneratia* cf. *kitchini* and/or *Cleoniceras* cf. *subbaylei* time).

The widespread presence and a predominantly argillaceous lithology of the marine early Albian rocks in the Mackenzie River valley and eastern Mackenzie Mountains (Hume, 1954) suggest the flooding of most or all of the present Mackenzie Mountains by the early Albian sea. This area is known to have been flooded already in the early lower Albian (i.e. in the *Sonneratia* cf. *kitchini* and/or *Cleoniceras* cf. *subbaylei* time; Warren, 1947; Stelck *et al.*, 1956, pp. 9, 10), but this sea apparently did not penetrate south of the Norman Wells-Wrigley area.

The widespread occurrence of marine late early Albian rocks (i.e. "*Lemuroceras* cf. *indicum*" to *Arcthoplites mcconnelli* zones inclusive; *see* Fig. 2) in the Liard River and Peace River drainage area (McLearn and Kindle, 1950; Stott, 1960) indicates that most or all of this area was flooded by the late early Albian sea.

The early lower Albian transgression in the Canadian Western Cordillera matches that of the Western Interior Region. Therefore, it breaks the regularity of the earlier Lower Cretaceous pattern (*see* p. 38) characterized by the opposition of the direction of contemporary tectonic movements in the geosynclinal and nongeosynclinal basins of Western and Arctic Canada.

The inferred maximum extent and configuration of the late lower Albian land and sea are shown in Figure 9. As already mentioned, they differ from those of the early lower Albian in a considerably greater extension of the seas in the Canadian Western Cordillera and in the Western Interior Region.

In the Western Cordillera the late lower Albian sea (*Brewericeras hulenense* time) appears to be considerably more widespread than the early lower Aptian sea (Jeletzky and Tipper, 1968, pp. 54-59, 84, 86; Tipper, 1969, p. 61 and unpublished data). Indurated or slightly metamorphosed Albian shales with the ammonite fauna possibly representing the *Brewericeras hulenense* zone occur in the Coast Mountains as far west as the Rivers Inlet area.

On the eastern side of Tyaughton Trough in Manning Park area the easterly overlap of the late lower Albian marine rocks is demonstrated by facies relationships and by the presence of the *Brewericeras hulenense* fauna in the upper part of the otherwise nonmarine Pasayten Group (Jeletzky, 1970b and unpublished).

In the Western Interior Region the late lower Albian Clearwater sea (i.e. *Arcthoplites mcconnelli* and? *Arcthoplites irenense* sea; Jeletzky, 1968a, pp. 16, 17) flooded all of the Peace River and Lower Athabasca areas according to Mellon and Wall (1956, p. 11) and Stelck *et al.* (1956, pp. 9, 10) but did not penetrate any farther south or east. However, Stelck (1958, Fig. 2) shows this sea as covering the headwaters of North Saskatchewan River east of Edmonton and this interpretation is followed in Figure 9.

Relatively little is known of the extent of the middle Albian *Grycia perezianum* sea in the Canadian Western Cordillera. So far as known, this middle Albian fauna is restricted to the same sections as the late lower Albian *Brewericeras hulenense* fauna (Jeletzky and Tipper, 1968, pp. 54-59, Table 2; Sutherland Brown, 1968, pp. 87-93; McLearn, in press) and the lithofacies of both zones are everywhere more or less the same. Therefore, it seems probable that the North Pacific middle Albian seas did not advance appreciable as compared with the late lower Albian sea (compare Fig. 9).

In the Western Interior Region the middle Albian sea (i.e. *Gastroplites* sea; Fig. 2) penetrated much deeper into the Great Plains and Rocky Mountain Region as compared with the late lower Albian sea (compare Stelck, 1958, Figs. 2 and 3). This sea was apparently the first to reach the International Boundary.

The latest middle Albian *Gastroplites*? *liardense* sea (Stelck *et al.*, 1956, pp. 6, 9; Stelck, 1958, pp. 3, 6, Fig. 3) apparently spread right across the Western Interior Region of the United States and established at least a tenuous connection with the contemporary Tethyan seas of the Gulf Coast. This is suggested by recent discoveries of *Inoceramus comancheanus* Cragin, *I. bellvuensis* Reeside, and *Dipoloceras* cf. *fredericsburgense* Scott in rocks of the *Gastroplites*? *liardense* zone in the Canadian Western Interior Region (Stelck *et al.*, 1956, pp. 6, 9; Stelck, 1958, pp. 3, 6).

In contrast to the early Albian marine rocks, the middle Albian marine rocks (i.e. zones of *Pseudopulchellia pattoni*, *Gastroplites canadensis* and *Gastroplites*? *liardense*) are unknown in the northern part of the Canadian Western Interior Region confined between the Liard River drainage area and the Arctic Coast. Still farther north the fossiliferous marine rocks of that age reappear in the Canadian Arctic Archipelago (Tozer and Thorsteinsson, 1964; Jeletzky, 1964). This circumstance and the appearance of thick, partly nonmarine arenaceous wedges (e.g. Commotion, Gates and Scatter Formations) in the latest lower and middle Albian rocks of the Peace River-Liard River drainage areas (McLearn and Kindle, 1950; Stott, 1961, 1967b, 1968) indicates uplift, closely to the west and northwest therefrom. These source areas (e.g. the Cassiar-Omineca Welt) apparently formed the southwestern fringe of a vast landmass comprising most or all of the Mackenzie Mountains, Mackenzie Lowlands west of Mackenzie River, Wernecke Mountains, most or all of the Porcupine and Eagle Plains, most or all of the Richardson Mountains and possibly the drainage areas of the Arctic Red and Peel Rivers. This landmass, which clearly emerged for the first time at the end of the early Albian (Arcthoplites mcconnelli time), is named herein the Mackenzie Salient. As it will be shown in the following sections, the behaviour of this positive tectonic element strongly influenced the paleogeography of the western part of the Canadian Western Interior Basin in the mid- to late Albian and throughtout the Upper Cretaceous.

The writer interprets the Cretaceous Mackenzie Salient as the reactivated southwestern part of an ancient (?late Precambrian), northeast-trending continental arch similar to Aklavik Arch (Jeletzky, 1961b, 1963) in its nature and tectonic behaviour. The Omineca-Cassiar Welt is interpreted as an independent (northwest-trending), much younger structure superimposed on the southwestern end of this ancient continental arch by the Middle Jurassic orogeny of the Cordilleran geosyncline. The Albian and Upper Cretaceous uplifts of the Mackenzie Salient may be related to the contemporary tectonic movements affecting the Omineca-Cassiar Welt.

No paleogeographical map of the middle Albian was drawn because of a close similarity of its Western Cordilleran paleogeographical pattern to that of the late lower Albian (Fig. 9) and the availability of a valid paleogeographical map for the Western Interior Region (Stelck, 1958, p. 6, Fig. 3).

The inferred general pattern of the late Albian land and sea is shown in Figure 10.

The fossiliferous marine late Albian rocks (*Mortoniceras* spp. and *Pseudouhligella dawsoni* zone; Fig. 2) are rare in the Canadian Western Cordillera (Jeletzky, 1967b, p. 67; Jeletzky and Tipper, 1968, pp. 54-59, Table 2; Sutherland Brown, 1968, pp. 87-93; McLearn, in press). However there is ample room for this late Albian zone in most predominantly argillaceous Albian sections of the region stratigraphically above the highest occurrence of early or middle Albian marine fossils. This circumstance and the far-reaching similarity of the lithofacies throughout the Albian sections of the Tyaughton and Insular troughs suggest that the extent of the North Pacific late Albian sea in the Canadian Western Cordillera was similar to that of the late lower and middle Albian seas (Figs. 9, 10).

The apparently complete absence of marine Albian rocks on the northwestern part of Vancouver Island (Jeletzky, 1970d) deserves to be noted. It seems that, unlike some other areas of the Canadian Western Cordillera uplifted by the Aptian tectonic movements, Vancouver Island continued throughout the Albian as an elevated source area locally flanked by nonmarine piedmont deposits (e.g. conglomerates of Quatsino Sound, pebbly greywackes of Tofino area).

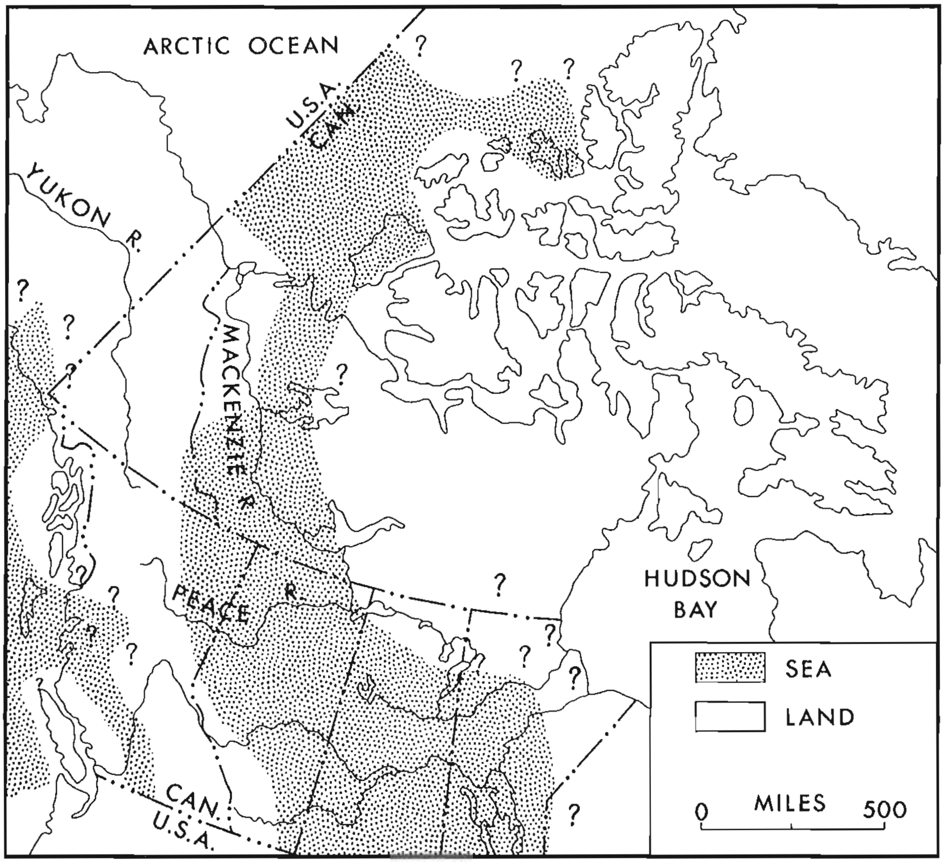


Figure 10. Late Albian paleogeography (≃ *Neogastroplites selwyni* time in the North American Boreal basins and *Mortoniceras* spp. time in the North Pacific basins). The map shows the inferred maximum extent of late Albian seas.

In the Western Interior Region the late Albian sea (*Neogastroplites* sea, Fig. 2) was definitely transgressive in the southern part of the region. There it reached the International Boundary on a wide front (Fig. 10) and spread far and wide in the Western Interior Region of the United States (Reeside, 1957, pp. 513-518, Figs. 5, 6; Reeside and Cobban, 1960, p. 9; Jeletzky, 1968a, pp. 20, 21).

The presence of *Metengonoceras* sp. (listed as *Engenoceras* (s. lato) sp. ind.) in the *Neogastroplites mclearni* zone of northwestern Alberta (Jeletzky *in* Thorsteinsson, 1952, p. 30) and in most *Neogastroplites* zones of the United States (Reeside and Cobban, 1960, p. 26) indicates that, like the latest middle Albian Boreal sea, the vast midcontinental *Neogastroplites* sea was directly connected with the late Albian Tethyan sea of the Gulf Coast.

The Boreal late Albian sea on the southern side of Mackenzie Salient was characterized by an irregularly oscillating tectonic regime which has resulted in a complex intertonguing of arenaceous and argillaceous wedges (Rudkin, 1964, p. 165, Fig. 11-6). However, there is no definite evidence of a major uplift such as characterized the late Albian farther north.

The Boreal late Albian sea was apparently more or less strongly regressive all over the eastern and northern flanks of the Mackenzie Salient. This regression, which represents a direct continuation of the previously described late middle Albian regression, is documented by an apparently total absence of late Albian marine fossils west of the Mackenzie River (unpublished fossil reports of the writer).

Throughout the Mackenzie Lowland the late Albian sea apparently retreated eastward beyond the Mackenzie Valley and Eskimo Lakes area. It seems probable, furthermore, that it retreated completely from the Arctic Coastal Plain west of Mackenzie Delta (Fig. 10).

In the Sverdrup Basin the late Albian sea was apparently restricted to the extreme northwestern edge of the Canadian Arctic Archipelago, judging by the almost total absence of marine fossils in the upper part of the Christopher Formation and the shallow water facies of the *Neogastroplites* n. sp. aff. *selwyni* McLearn beds in the so far unique fossiliferous late Albian section on Thomsen River, Banks Island (GSC loc. 75251, 75253, 75256; unpublished fossil report of the writer).

The discovery of *Metengonoceras* in *Neogastroplites* zone of the midcontinent, more recent discovery of *Neogastroplites* fauna in the Canadian Arctic Archipelago, and its reported presence in northeastern Siberia (Pergament, 1969, p. 114) discredit Warren and Stelck's (1959, p. 18) and Stelck's (1967, pp. 41, 42 and paleogeographical map of Mowry Sea) idea that the obviously restricted character of marine communications of the late Albian seas of the Canadian Western Interior Region amounted to a complete closure of its Boreal and Tethyan links and a formation of (Warren and Stelck, 1959, p. 18): "a landlocked sea (Mowry) that covered most of northeastern British Columbia, Alberta, southern Saskatchewan, eastern Montana, the Dakotas, Wyoming, Nebraska, and possibly Colorado". As already stressed in this section and elsewhere (p. 26) the paleobiotic data available clearly indicate the continuous existence of admittedly more or less restricted seaways connecting the midcontinental *Neogastroplites* or Mowry sea with the contemporary Boreal seas of the Canadian and American Arctic and with the Tethyan seas of the Gulf of Mexico region. It is, furthermore, most unlikely that a completely landlocked Western Interior Mowry Sea postulated by Warren and Stelck (1959) and Stelck (1967) could have maintained a normal to near normal salinity, which is demanded by the continuous presence of ammonites in its waters, for at least a few millions of years in late Albian time.

The extremely rich North Pacific Albian marine faunas of the Canadian Western Cordillera (pp. 25, 26, Table 6) have almost nothing in common with the extremely strongly depauperated, contemporary Boreal faunas of the Canadian Western Interior and Arctic Regions. This clearly indicates the absence of any direct marine connections between the North Pacific and Boreal basins of Canada throughout the Albian (Figs. 9, 10). The sites of the Neocomian Dawson City and Vanderhoof Straits obviously remained elevated well above sea level.

Cenomanian

The Cenomanian paleogeography summarized in Figure 11 differs from the Albian paleogeography in an apparently complete retreat of the North Pacific seas from the mainland of western British Columbia and southwestern Yukon. So far as known, only nonmarine volcanic and sedimentary Cenomanian rocks were deposited in the depressed areas of this region (Jeletzky and Tipper, 1968, p. 86, Fig. 10).

In the Insular part of western British Columbia, the marine Cenomanian rocks appear to be restricted to Queen Charlotte Islands (Sutherland Brown, 1968, pp. 87-93; McLearn, in press) and the northwestern end of Vancouver Island (Jeletzky, 1970d). The predominantly argillaceous

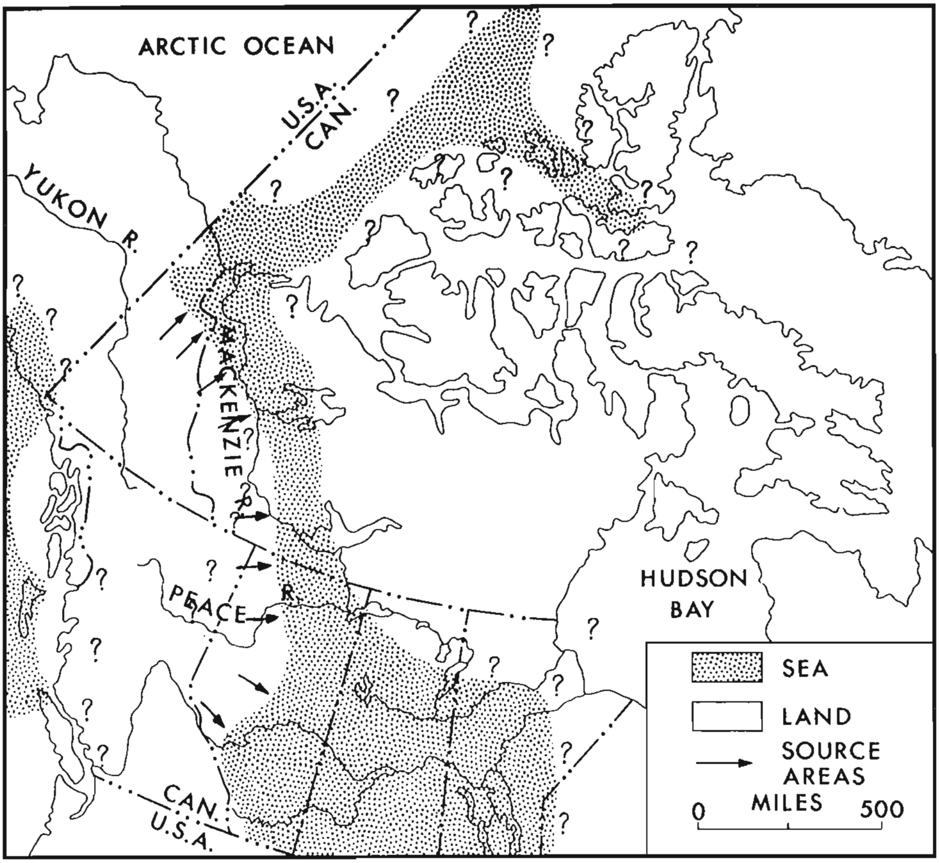


Figure 11. Late Cenomanian paleogeography (Dunvegan or *Acanthoceras athabascense* time in the North American Boreal basins and *Eucalycoceras*? ex aff. *shastense* time in the North Pacific basins). The map shows the inferred maximum extent of late Cenomanian seas.

facies of the early Cenomanian deposits contrast with the sandy lithology of the underlying marine Albian rocks on Queen Charlotte Islands (Sutherland Brown, 1968). On northern Vancouver Island the predominantly argillaceous early to late Cenomanian rocks overlap the Aptian-Albian conglomerate unit and are obviously transgressive to the south (Jeletzky, 1970d). This indicates a limited eastward transgression of the North Pacific Cenomanian sea following a strong regional uplift of the Canadian Western Cordillera in the latest Albian time.

In the Canadian Western Interior Region the Cenomanian sea appears to be somewhat transgressive in the Richardson Mountain-Porcupine Plain Basin judging by the pure shale lithology of *Inoceramus crippsi* beds in Aklavik Range (Jeletzky, 1960, pp. 20, 21). Reliably dated marine Cenomanian rocks are absent elsewhere in this basin and their areal extent shown in Figure 11 is conjunctural.

The Cenomanian sea may be more or less strongly transgressive in the Lower Mackenzie Basin if the argillaceous Slater River Formation (Hume, 1954, pp. 49, 50) includes rocks of that age.

Still farther south the Cenomanian sea is strongly regressive. Strong but shortlived uplifts, which occurred in the mid?-Cenomanian along the southeastern margin of the Mackenzie Salient (Fig. 11) have resulted in the formation of the well-known Dunvegan-Fort Nelson Delta in the basins of Liard and Peace River (McLearn, 1945b; McLearn and Kindle, 1950; Stelck and Wall, 1955, pp. 17, 18, Fig. 5; Stott, 1960; Williams and Burk, Jr., 1964, p. 178). Throughout this area the mostly nonmarine arenaceous to psephitic Dunvegan (= Fort Nelson) rocks overlie marine beds of Fort St. John Group.

In contrast, the Cenomanian sea must have been markedly transgressive everywhere in the Southern Foothills as the Cenomanian marine shale of the Lower Blackstone Formation overlies the nonmarine Albian rocks over much of this area (Stelck, 1958, p. 3; Stott, 1960, p. 4, Table 1; 1961, 1963; Williams and Burk, Jr., 1964, p. 182; Jeletzky, 1968a, pp. 22, 23). The Cenomanian sea apparently advanced southward and southwestward in the southern part of the Foothills Belt (Jeletzky, 1968a, pp. 22, 23). North of Athabasca River, however, the late Cenomanian sea advanced northward and westward gradually overlapping the nonmarine to brackish sands of the southern part of the Dunvegan Delta. This process is well illustrated by the occurrence of the late Cenomanian *Dunveganoceras*-bearing shales of the basal Kaskapau Formation stratigraphically above the older Cenomanian Dunvegan sandstones in many sections of the Peace River drainage area (e.g. McLearn, 1945b; McLearn and Kindle, 1950; pp. 103, 105; Stelck and Wall, 1955, pp. 16-19, Fig. 5). Therefore the late Cenomanian (*Dunveganoceras* time; Fig. 2) transgression of the Foothills Belt must have reached a structural low within the northern Foothills (southeast of Dunvegan Delta) before invading their more southeasterly and northwesterly parts (L.S. Russell, 1939, p. 82).

As already mentioned (pp. 15, 28), the relative diversity and composition of the Cenomanian fauna of the Western Interior Region of Canada indicates a marked improvement of the marine connections between this Boreal sea and the Tethyan seas of the Gulf Coast as compared with late Albian time. The Cenomanian in Canada was, therefore, characterized by widespread transgression of the midcontinental Boreal sea. The already mentioned short-lived uplifts on the western side of this basin appear to be only local complicating features connected with the tectonic movements within the Mackenzie Salient but with little or no regional repercussions south of the Liard-Peace River drainage areas or north of Mackenzie and Wernecke Mountains.

The so far unique occurrence of marine Cenomanian fossils in the lower part of Kanguk? Formation on Graham Island, Canadian Arctic Archipelago atop the presumably nonmarine beds of Hassel? Formation (Greiner, *in* Fortier *et al.*, 1963, pp..410, 411) suggests that the Cenomanian transgression also affected this region. Its areal extent is unknown. However, the apparent absence of Cenomanian marine fossils in the Upper Cretaceous sequence of the Disco Bay area (Birkelund, 1965) suggests that the lasting early to latest Upper Cretaceous marine connection between the West Greenland sea and that of the Canadian Arctic Archipelago was not yet established in the Cenomanian (Fig. 11).

The argillaceous lithology and the apparent absence of shoreward facies changes in the Cenomanian upper member of Ashville Formation (Wickenden, 1945, p. 17) suggest that the eastern shore of the midcontinental Cenomanian sea was a considerable distance east of the present eastern margin of the Cretaceous rocks in eastern Manitoba which represents only their erosional edge.

Turonian

The Turonian paleogeography is shown in Figures 12 and 13 because of a marked difference known to exist between the early and late Turonian paleogeographies.

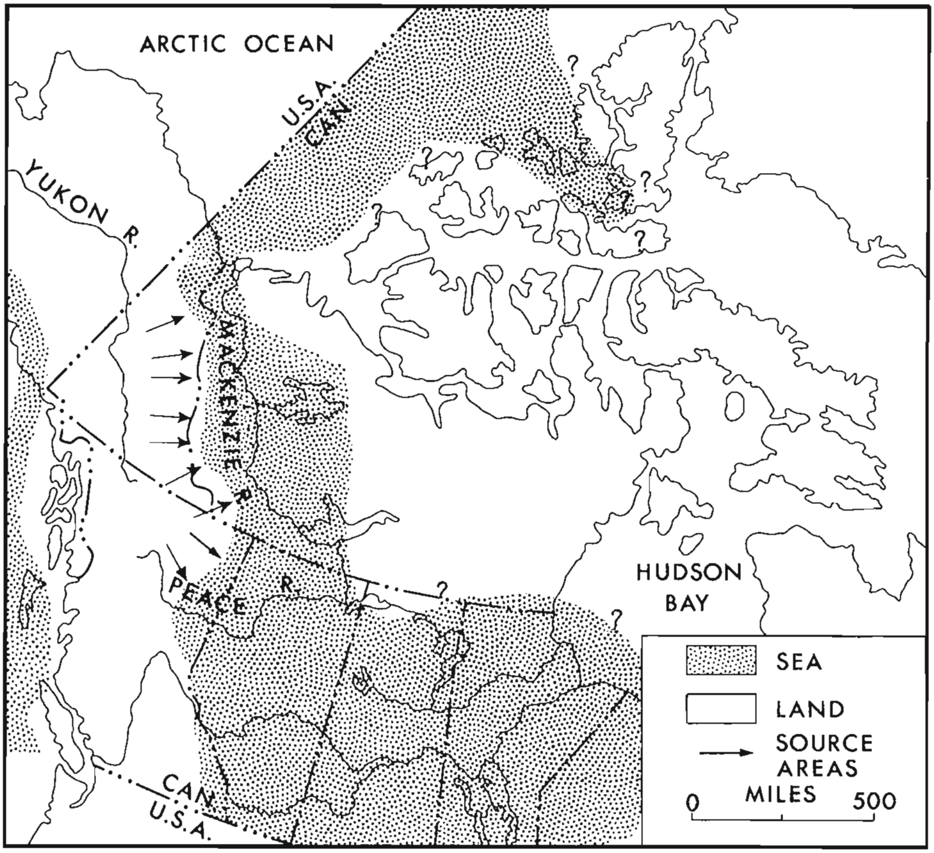


Figure 12. Early Turonian paleogeography (*Inoceramus labiatus* time). The map shows the inferred maximum extent of lower Turonian seas.

The North Pacific Turonian seas apparently were restricted to the same areas off the mainland of British Columbia as were the Cenomanian seas (Figs. 11, 12). At least there are no indications of the Turonian transgression anywhere in the Insular Belt. Volcanic and sedimentary nonmarine rocks continued to form in the depressed part of the British Columbia mainland (Jeletzky and Tipper, 1968) and the same is probably true of the southwestern Yukon.

The early Turonian (*Inoceramus labiatus* time; Fig. 3) is customarily considered to be the time of the maximum Cretaceous transgression of the Canadian Western Interior Region (e.g. L.S. Russell, 1939, p. 82, Fig. 1; Stelck and Wall, 1954, pp. 14-17; Williams and Burk, Jr., 1964, p. 188). This view is not an entirely correct one as the mid- to late Santonian sea certainly covered a considerably larger area in the Western Interior Region and the Canadian Arctic Archipelago than did the early Turonian sea (compare Figs. 12 and 14). However, the early Turonian transgression is by far the second greatest in this region.

The widespread lower Turonian transgression of the Canadian Western Interior Region represents a direct continuation of the previously described late Cenomanian transgression (Figs. 11, 12). The strongly diversified and uniquely cosmopolitan character of the lower Turonian macrofauna and the sudden influx of the cosmopolitan pelagic foraminifers at the onset of the Turonian attest to further widening and deepening of the seaways connecting the Canadian Western Interior Basin with those of northern Alaska and the Gulf of Mexico (Stelck and Wall, 1954, pp. 14-16; this paper p. 28).

The great extent of the lower Turonian sea in the Western Interior of Canada is indicated by the prevalence of more or less limy, speckled shale or marl rich in coccoliths, rhabdoliths, and planktonic foraminifera throughout the Great Plain Region and by its spread well into the Foothills Belt (Williams and Burk, Jr., 1964, pp. 170-172, Figs. 12-2 - 12-7). This facies indicates a pelagic environment and suggests the depth of water in excess of 1,000 feet according to Stelck and Wall (1954, p. 17).

As shown in Figure 12, the western shoreline of the early Turonian sea was situated well west of the present day Rocky Mountain front as illustrated by the presence of *Inoceramus labiatus* beds in the Crowsnest Pass near the Continental Divide (Stelck and Wall, 1954, p. 15; Stott, 1963, pp. 45, 148, Fig. 15c; Jeletzky, 1968a,p. 22) and in the Tuskoola Sandstone of the Upper Pine River area (Williams and Bocock, 1932; McLearn and Kindle, 1950, p. 103; Stott, 1967b, pp. 24-26).

The complete absence of the marine early Turonian rocks north of the Upper Pine and Lower Smoky River areas was explained by the complete removal of the Kaskapau and Cardium rocks in the Liard River basin during the latest Turonian uplift and erosional interval (Stelck, 1955, p. 3, Fig. 1; Stott, 1960, p. 17). This hypothesis was, however, discredited by later work of Stott (1967b, pp. 32, 35, 36) and it appears much more probable that most or all of the Liard River-Mackenzie Mountain drainage area remained above sea level during the peak period of the early Turonian transgression forming an eastward convex promontory (Fig. 12). The southern side of this remnant of the late Albian Mackenzie Salient provided sandy to conglomeratic detritus to the neritic early Turonian rocks of the Upper Pine River area.

According to Dr. C.R. Stelck (pers. comm., October 23, 1969) the *Watinoceras* and *Scaphites delicatulus* fauna of the Bear Rock locality described by Warren (1947) was collected from the Slater River shale. The lower Turonian rocks of the Norman Wells area are therefore represented by an open sea facies matching that of the Aklavik Range in the northwest (Jeletzky, 1960, p. 22) and that of the Vimy Member of the Kaskapau Formation in the south (Stott, 1967b, pp. 21-22). The shoreline of the early Turonian sea must have been situated well to the west of the Mackenzie Valley. Its position within the present day Mackenzie Mountains is uncertain as we do not know of any outcrops of the neritic early Turonian rocks west of those of the Slater River shale. It seems likely that the wide early Turonian seaway connecting the basin of the Great Plain and Foothill Regions with the Richardson Mountain-Porcupine Plain basin and the Sverdrup basin covered a considerable part of the Mackenzie Salient west of the Mackenzie River (Fig. 12).

In the east this seaway extended beyond Great Bear Lake, as indicated by the recent discovery of the early Turonian marine fossils on Lac des Bois. This fauna occurs in a Favel-like facies and includes *Inoceramus labiatus* Schloth., *Scaphites delicatulus* Warren, *Otoscaphites* cf. *seabeensis* Cobban and Gryc, *Borissiakoceras* cf. *ashurkoffae* Cobban and Gryc and a kelaenid teuthid (unpublished fossil report of the writer). This fauna is identical to those described by Warren (1947) from the Slater River shale of the Mackenzie Valley and by Cobban and Gryc (1961) from northern Alaska.

The presence of an argillaceous facies of the lower Turonian closely matching the second White Specks facies of the Great Plains in the Aklavik Range of Richardson Mountains (Jeletzky, 1960, p. 22) indicates the flooding of most or all of the northern Richardson Mountains by the early Turonian sea. It is concluded therefrom that the early Turonian sea covered most or all of the Arctic Red and Peel River drainage area and may have reached the eastern side of the present Wernecke Mountains (Fig. 12).

The writer assumes the flooding of much of the Richardson Mountain-Porcupine Plain Basin by the early Turonian sea in spite of the complete absence of supporting faunal evidence (Fig. 12). This sea may have extended to the eastern side of the present Ogilvie Mountains.

There is no record of lower Turonian marine sedimentation anywhere on the Arctic Coastal Plain east of Mackenzie Delta. This area apparently formed part of Aklavik Arch throughout the Cretaceous (Jeletzky, 1961b) and is therefore assumed to be emergent, except for the part adjoining the Richardson Mountains from the east (Fig. 12). The latter apparently more or less continuously depressed part of the Aklavik Arch is believed to be submerged and to form the eastern part of a wide seaway connecting the early Turonian seas of the mainland with those of northern Alaska (Fig. 12).

The apparent absence of lower Turonian marine sediments in the Canadian Arctic Archipelago and in the Disco Bay area of western Greenland (Tozer and Thorsteinsson, 1964; Fortier *et al.*, 1963; Birkelund, 1965) suggests a complete emergence of these regions. The apparently regressive behaviour of these early Turonian seas is in contrast with the strongly transgressive nature of those of the more southerly regions.

The eastern margin of the early Turonian sea is postulated somewhere on the western flank of the Canadian Shield because of the apparently complete absence of any shallow water facies of that time in eastern Manitoba (Wickenden, 1945, p. 23).

The gradual shaling out of the grey marls of the Favel Formation to the north (Williams and Burk, Jr., 1964, p.172) suggests that the northeastern shoreline of the lower Turonian sea was far removed from the northern margin of its present day outcrop area in Manitoba which, like the eastern margin, is only an erosional edge. The writer has therefore assumed the flooding of much of the Hudson Bay area during the peak period of the early Turonian transgression in spite of the absence there of any known outcrops of the marine Cretaceous.

In contrast to early Turonian time, the late Turonian was a time of a strong regression over much of the Western Interior Region (Fig. 13). This regression must have begun already in the mid-Turonian (*Prionocyclus woollgari* s. str. time; Fig. 3) if one accepts Williams and Burk's Jr. (1964, p. 188) suggestion concerning the regressive character of dark grey to black, noncalcareous shale which was deposited over most of the Great Plain and Foothill regions at that time.

On the eastern side of the Canadian Western Interior basin the deposition of dark grey noncalcareous shale of the Morden Member (Wickenden, 1945, p. 33; Jeletzky, 1968a, p. 31 and unpublished identification of *Prionocyclus hyatti* from Morden Member by the writer) only began in late middle Turonian time and probably lasted well into late Turonian time (Jeletzky, 1968a, p. 33). This suggests that this side of the basin was only slightly affected by the late Turonian regression.

On the western side of the basin, in contrast, the deposition of the mid-Turonian shale was followed by the deposition of sandy to conglomeratic clastics of the late Turonian Cardium Formation (Stott, 1961, 1963, 1967b, 1968; Williams and Burk, Jr., 1964, pp. 172, 173, Figs. 12-2, 12-4; Jeletzky, 1968a, pp. 30, 31). The Cardium consists of neritic to brackish-water clastics interbedded with beach, barrier island, lagoon and tidal swamp deposits.

Unlike the predominantly deltaic clastics of the Dunvegan Formation, the Cardium clastics were deposited all along the Foothills Belt and were derived from a western source area which flanked their outcrop between the Peace River drainage area and the International Boundary. As pointed out by Stott (1963, p. 137): "The greatest development of lagoonal deposits in the Cardium Formation lies towards the west, and the barriers lie to the east (*see* Figs. 19a, 19b). The marked thickening of the sections towards the west, the gradual increase in sand content in that direction, the change from shale, through sandstone to brackish-water facies and coal beds likewise indicate a western source." At the same time the Cardium Formation becomes progressively

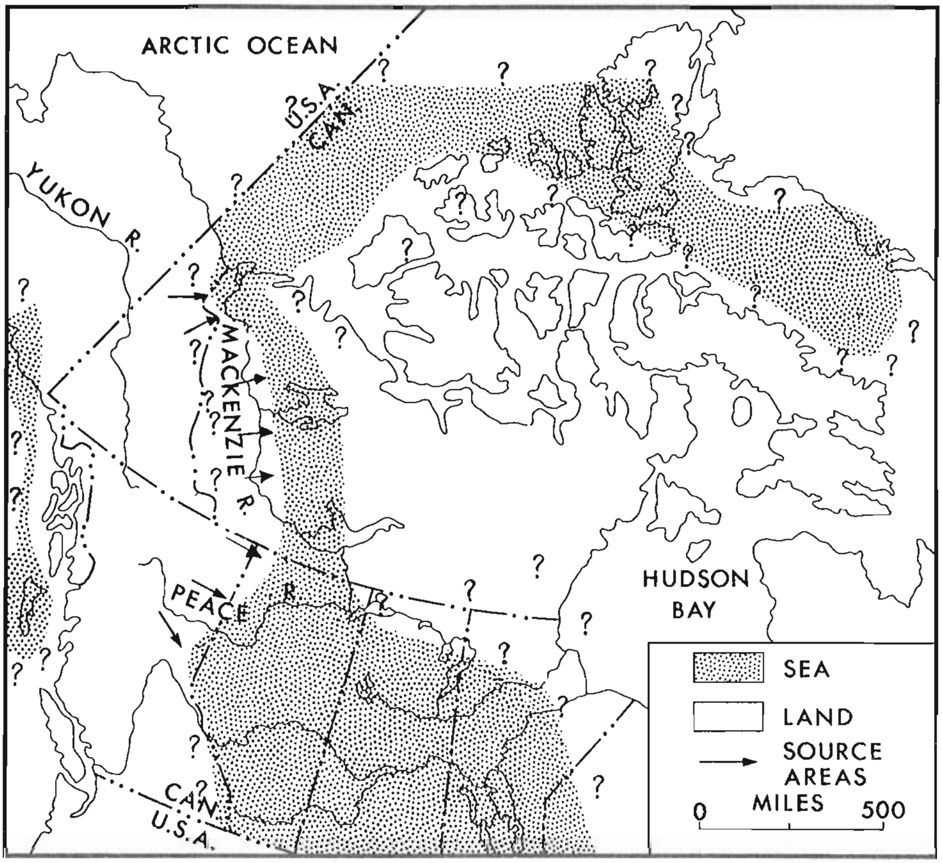


Figure 13. Late Turonian paleogeography (Cardium or *Arctostrea lugubris* time in North American Boreal basins). The map shows the inferred maximum extent of late Turonian regression in the Western Interior and Western Cordilleran Regions.

less conglomeratic and sandy, and at the same time less and less widespread areally in the southwestern direction along the Foothills Belt (*see* in Williams and Burk, Jr., 1964, pp. 172, 173; Stott, 1967b, Fig. 10). The ratio of nonmarine rocks within the Cardium Formation also decreases gradually in this direction until the formation becomes predominantly marine and largely argillaceous in the southern Foothills between Fallen Timber Creek and Highwood River (Stott, 1961, pp. 61, 62, Fig. 5; 1967b, p. 38, Fig. 10). These facies changes may well be related, in part, to the north-south rather than northwest-southwest direction of the western shore of the late Turonian (Cardium) sea and the oblique angle it forms with the trend of the Foothills Belt. However, they also must reflect the re-emergence of the southern part of Mackenzie Salient as an elevated source area in the Peace River Foothills and Plains (Fig. 13). This is indicated by an apparently complete absence of Turonian and probably Coniacian rocks north of Peace River stressed by Stott (1967c, p. 19) and Taylor and Stott (1968a, p. 19; 1968b, p. 19) and the transgressive overlap of the Santonian Kotaneelee equivalents on the basal Kaskapau or Dunvegan Formation. The Cardium sea of the Foothills Belt is therefore believed to have occupied an embayment confined between a western landmass situated to the west of the Foothills Belt and the southern side of the eastward-protruding Mackenzie Salient occupying the Liard River drainage area (Fig. 13).

The uplifts along the western margin of the Cardium sea caused a marked eastward retreat of the western shoreline of this latest Turonian sea (*Prionocyclus wyomingensis* and *Scaphites corvensis* time; *see* Fig. 13). The uplifts along the southern margin of the Mackenzie Salient caused an even more marked southward and southeastward retreat of this sea as indicated in Figure 13. Marine upper Turonian rocks are unknown anywhere in the northern Yukon and Northwest Territories, including the Canadian Arctic Archipelago. The records of *Inoceramus* ex gr. *lamarcki* or *inconstans* on Porcupine River (*see* p. 59) are now believed to indicate a Coniacian rather than a late Turonian age of the rocks concerned.

Dr. C.R. Stelck (pers. comm., October 23, 1969) has brought to the writer's attention the discovery of a large *Inoceramus* of early Upper Cretaceous affinities in the Little Bear Formation on Little Bear River (Hume, 1924, p. 4B, Pl. 1A). According to him the Little Bear Formation overlies the lower Turonian Slater River shale. Therefore, the marine to nonmarine sandstones of the Little Bear Formation (Hume, 1924, p. 4B; 1954, pp. 48-51) appear to be roughly equivalent to the Cardium sandstones of the Foothills Belt. This indicates that most or all of the part of Mackenzie Salient flooded by the early Turonian transgression was uplifted above sea level in the late Turonian.

The revision of age and stratigraphic relationships of the Little Bear Formation recently suggested by Mountjoy (*in* Mountjoy and Chamney, 1969, p. 3, text-fig. 4) is just as unfounded as is his revision of age and stratigraphic relationships of Slater River and East Fork Formations (*see* pp. 51, 58).

Warren and Stelck (unpublished manuscript) have concluded from the widespread occurrence of the late Turonian uplifts that the Arctic outlet of the Canadian Western Interior Region was closed in the late Turonian. However, the writer postulates the presence of a relatively narrow late Turonian seaway east of Mackenzie River and in the structurally negative area around its mouth (Fig. 13) because of the presence of an ammonite closely resembling a diagnostic North American late Turonian species *Scaphites corvensis* Cobban in the Disco Bay area of West Greenland (Birkelund, 1965). *Scaphites* of this type are native to the Western Interior sea of North America and do not penetrate into the Tethyan sea of the Gulf Coast (Cobban, 1951). Their presence in West Greenland constitutes, therefore, a reliable indication of the existence of a direct marine connection between these two basins (Gill and Cobban, 1966, p. 43). It is suggested accordingly that the lasting early to latest Upper Cretaceous marine connection between the West Greenland sea and that of the Canadian Western Interior Region discussed in the following sections opened up in the late Turonian (Fig. 13). Like Teichert (*in* Ruedemann and Balk, 1939, pp. 154-156, Fig. 12), most of the later workers including the writer (Jeletzky, 1950, p. 23; Birkelund, 1965, p. 168, Fig. 125; Gill and Cobban, 1966, pp. 43-44, Fig. 15) prefer to place this late Turonian seaway across the Mackenzie Lowlands, beneath the Beaufort Sea and across the southern part of Ellesmere Island, as these areas contain marine Cretaceous rocks of several ages. The alternative hypothesis of a marine seaway across Hudson Bay and northern Baffin Island or across the Archipelago north of Baffin Island (Rosenkrantz *et al.*, 1942, p. 39) appears to be much less probable and so is not favoured in this report. However, it cannot be ruled out in the present state of our knowledge.

Coniacian to Mid-Santonian

The generalized treatment of the Coniacian and early to mid-Santonian paleogeography under one heading was necessitated by the paucity of data, apparent similarity of the overall geographic pattern throughout this

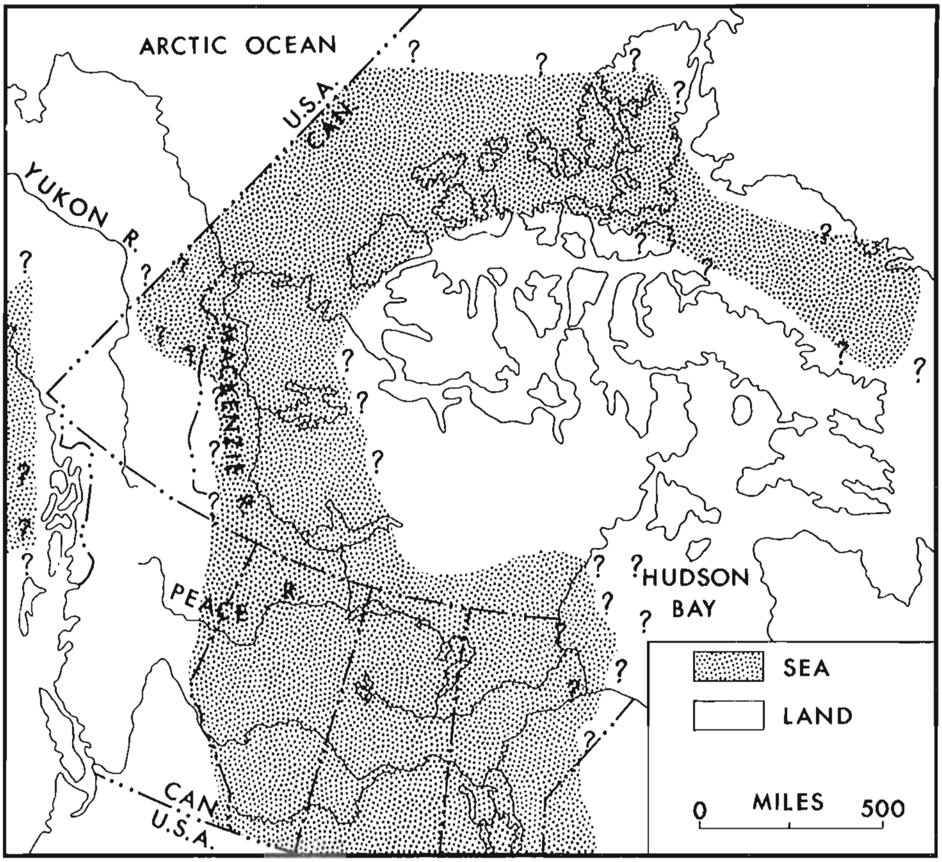


Figure 14. Coniacian and lower to mid-Santonian paleogeography (from *Scaphites ventricosus* to *Clioscaphites montanensis* time inclusive in the North American Boreal basins; no marine rocks are known in the North Pacific Province). Generally speaking, the map shows the inferred mid-Santonian maximum extent of Coniacian and lower to mid-Santonian transgression in the Western Interior Region.

long interval of geological time and by considerable differences of opinion among Canadian workers who have attempted to delimit the Santonian stage from the Coniacian and Campanian stages and subdivide it into paleontological zones. This problem was recently discussed by the writer (Jeletzky, 1967a, p. 70; Jeletzky, 1968a, pp. 34-36; Muller and Jeletzky, 1967, pp. 41, 42) and the Santonian stage is here used and zoned essentially in accordance with his conclusions (Fig. 3). Unfortunately, it was often found difficult to reinterpret differing usages of previous workers in terms of these ideas. This has prevented the writer from drawing separate paleogeographical maps for the Coniacian and early to mid-Santonian. So far as they are known or assumed to exist, the major differences of the Coniacian and early Santonian paleogeographic patterns are discussed below.

No marine Coniacian and early to mid-Santonian rocks are known anywhere in the Canadian Western Cordillera (Fig. 14). Their presence in Queen Charlotte Islands could, however, be assumed because of the presence of a thick succession of the Upper Cretaceous clastics of the Honna and Skidegate Formations stratigraphically above the Haida Formation which includes some early Turonian *Inoceramus labiatus*? beds (Sutherland Brown, 1968, p. 92). The Honna and Skidegate Formations are at least partly marine, as they have yielded some poor ammonites and inocerami unsuitable for a refined dating (Sutherland Brown, 1968, pp. 98, 104).

Imlay and Reeside's (1954, pp. 232, 233, 239) claim of the presence of Coniacian rocks in the Haslam Formation of eastern Vancouver Island is an error caused by the misidentification of the Campanian *Inoceramus* (*Schmidtoceramus*) *schmidti* Michael and *I. vancouverensis* Shumard with the homeomorphically similar Coniacian inocerami of the Western Interior and Gulf Regions of the United States (*see* Jeletzky, 1967a, p. 70 and Muller and Jeletzky, 1967, pp. 41, 42, Table 1).

In the Canadian Western Interior Region and the Canadian Arctic Archipelago the Coniacian to mid-Santonian was the time of the greatest marine transgression, which reached its peak sometime between the end of *Scaphites* (*Clioscaphites*) *montanensis* and the later part of *Desmoscaphites* spp. time as defined by Jeletzky (1968a, pp. 40-43) for the Canadian Western Interior Region.

As already pointed out (p. 29) the Coniacian to mid-Santonian ammonite faunas of the Boreal sea of the Canadian Western Interior Region are less diversified and more provincial than those of the Turonian (especially early Turonian) sea of the same region. However, this apparently was caused not by the geographical isolation of this basin but by an appreciable deterioration of the climatic conditions in Coniacian-Santonian time which favoured faunal exchanges with the Boreal basins of the American and European Arctic and limited those with the Tethyan seas of the Gulf Coast. The remarkable southward migration of the characteristic Boreal inocerami (*Sphenoceramus* and *Volviceramus*) and *Actinocamax* (Jeletzky, 1950) forms in the Coniacian-Santonian supports this conclusion.

The gradual widening and deepening of the Coniacian to mid-Santonian seaways connecting the Canadian Western Interior Basin with those of the North American Arctic and the Gulf of Mexico is clearly indicated by the presence of *Uintacrinus*, *Inoceramus stantoni* and other cosmopolitan or Pacific macrofossils. It is, furthermore, indicated by the gradually increasing influx of the planktonic foraminiferal fauna of the First Speckled Shale (Wall, 1960; Wall and Germundson, 1963, pp. 342-343).

The Coniacian to mid-Santonian transgression resulted in the prevalence of an open sea shale facies in the Great Plains and Foothills Regions. Deposition of more or less limy, speckled shale rich in coccoliths, rhabdoliths, and planktonic foraminifera was common in the Great Plains Region and locally occurs in the Foothills Region (Wall, 1960, p. 12; Wall and Germundson, 1963), especially at the mid-Santonian peak of the transgression. Like the early Turonian Second Speckled Shale, the Coniacian to earliest Campanian First Speckled Shale indicates an open sea (or pelagic) environment with the depth of water in excess of 1,000 feet.

It must be stressed in this connection that the boundaries of the First Speckled Shale are strongly diachronic from one area to another and that the unit appears to include a much longer biochronological interval under the eastern Great Plains than either under the western Great Plains or in the Foothills Belt. The following information is provided by the largely unpublished identifications of diagnostic macrofossils from the First Speckled Shale.

Along the Manitoba Escarpment the First Speckled Shale (Boyne Member) extends at least from the uppermost Turonian *Scaphites preventricosus* zone to the top of the lower Campanian *Hoploscaphites hippocrepis* zone, judging by the matrix of numerous index fossils from that area preserved in the Geological Survey of Canada collections. The presence of the late lower Campanian rocks in the Boyne Member is indicated by the presence of a solitary specimen of

Haresiceras found and generically identified by S.R. Kirk (*see* McLearn, 1937, p. 118). This specimen was more recently identified as *H. natronense* Reeside by Jeletzky (1970a, Pl. IV, Fig. 5).

In the Lloydminster area of western Saskatchewan and in the Lower Athabasca River area the lower Campanian *Hoploscaphites hippocrepis* zone occurs in the basal part of the First Speckled Shale. In the former area *H. hippocrepis* was found in association with the *Trochammina ribstonensis* fauna (Jeletzky, 1968a, pp. 43, 44). This indicates that the base of the First Speckled Shale in the Lloydminster and Athabasca areas is equivalent to the topmost beds of the same unit along the Manitoba Escarpment. If one accepts the insufficiently founded conclusion (e.g. Williams and Burk, Jr., 1964) that there is only one First Speckled Shale Unit which persists right across the Great Plain Region, the west-east diachronism of this unit is pronounced indeed.

In the Smoky River area, in contrast, the First Speckled Shale of the Thistle Member appears to be restricted to the late mid-Santonian *Scaphites* (*Clioscaphites*) *montanensis* zone and the lower part of the late Santonian *Desmoscaphites* spp. zone (Stott, 1967b, pp. 52-55). The same appears to be true of Central and Southern Foothills (Wall and Germundson, 1963, pp. 334, 342, 343; Stott, 1963, pp. 99-103) where the First Speckled Shale is again represented only by the Thistle Member of the Wapiabi Formation. The same conclusion was independently reached by T.P. Chamney on the basis of a regional analysis of topmost occurrences of *Hedbergella delrioensis* in relation to the First Speckled Shale beds (pers. comm., October 22, 1969).

The above biochronological data discredits the widespread assumption recently expressed by Wall and Germundson (1963, p. 345) that the base of the upper Speckled Shale beds with the associated upper pelagic microfauna is a reliable datum plane representing: "time lines more accurately than could any other microfaunal, megafaunal or lithological criteria presently known within this sequence."

The writer interprets the First and Second Speckled Shale as peculiar bio- and lithofacies characterized by the "incipient chalk deposition" and reflecting temporary paucity of terrigenous sediments during the time of maximal widening and deepening of the Upper Cretaceous seas of the Canadian Western Interior Region. Though obviously confined to exceptional and relatively narrow time intervals of the Upper Cretaceous history of this basin, the "White Specks" facies obviously cannot be expected to represent better datum planes than the well tested, short ranging and facies-breaking macrofossils, such as ammonites or inocerami.

An areally restricted and short-lived Badheart regression occurred in the earliest Santonian (*Scaphites depressus* time; Stott, 1967b, p. 48; Jeletzky, 1968a, p. 36)[1]. The neritic to nonmarine sandstone wedge (Badheart Member) deposited during this regression is essentially restricted to the Peace River Foothills and Plains (Stott, 1963, p. 47; 1967b, pp. 44, 49; Williams and Burk, Jr., 1964, Figs. 12-2, 12-4) and was obviously caused by an uplift and erosion of the Mackenzie Salient. As the Badheart regression only briefly interrupted the spread of the Coniacian-mid-Santonian transgression and was apparently not felt at all over most of the Canadian Western Interior basin, no special paleogeographical map was prepared for earliest Santonian time.

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[1] Stelck (1955, p. 2) records the diagnostic early upper Santonian *Scaphites* (*Clioscaphites*) *montanensis* Cobban from the Badheart Sandstone. Thanks to the kind co-operation of Dr. C.R. Stelck this anomalous specimen was examined by the writer in the University of Alberta, Edmonton collections. The preparation of the suture line has revealed that this specimen belongs to the earliest Santonian *Scaphites* (*Scaphites*) *depressus* Reeside. Dr. C.R. Stelck concurs with this conclusion.

The Badheart regression of the Peace River Foothills and Plains appears to be expressed as a considerable erosional hiatus and geographical unconformity north and northwest of the Badheart arenaceous wedge (Stott, 1960, pp. 18, 19; 1967c, p. 19; Taylor and Stott, 1968a, p. 19; 1968b, p. 19). The combined effect of the Cardium and Badheart uplifts was apparently lasting enough to keep the Turonian and Coniacian seas out of the Liard River-Mackenzie Mountain landmass (Mackenzie Salient of this paper) until the early Santonian (Kotaneelee time). This prolonged period of nondeposition and/or erosion appears to be responsible for the transgressive overlap of the largely argillaceous and marine Kotaneelee Formation on the nonmarine Cenomanian (i.e. Dunvegan) rocks. The combined effect of these late Turonian and latest Coniacian tectonic pulses was interpreted as the "Upper Cardium" unconformity by Stelck (1955, pp. 3, 4, Fig. 1) because of an insufficient paleontological control.

At its mid-Santonian peak shown in Figure 14 the Coniacian-mid-Santonian transgression had spread well beyond the shorelines of the early Turonian sea in all marginal areas of the Canadian Western Interior basin for which the data are available.

As pointed out by Stott (1963, pp. 127, 128, 150, 151; 1967b, pp. 52, 55) the Coniacian to mid-Santonian (i.e. early to mid-Wapiabi) seas were transgressive all along the Foothills Belt. The outcrops of marine shales of Dowling and Thistle members occur as far west as those of *Inoceramus labiatus* (Vimy) shale. The facies of these two transgressive shale units are closely similar and it is obvious that the shoreline of the mid-Santonian sea of the Foothills Belt was situated at least as far west as that of the early Turonian sea. The data available for other areas suggest that it actually overstepped the shoreline of the early Turonian sea throughout the Foothills Belt and this interpretation is favoured in Figure 14.

Farther north along the western side of the basin, the already mentioned overlap of considerable parts of the Liard River drainage area by the early Santonian (and later?) Kotaneelee shale (Stott, 1960, pp. 18, 19; 1967c, p. 19; Taylor and Stott, 1968a, p. 19; 1968b, p. 19) attests to the spread of the Coniacian-mid-Santonian transgression far beyond the shoreline of the Turonian sea preserved in the Upper Pine River area. The still unknown neritic facies of the upper part of the Kotaneelee Formation must have been situated still farther west and north of its now known outcrops.

The marine shale of East Fork Formation overlies the sandstone of Little Bear Formation (Hume, 1924, p. 4B; 1954, pp. 48-51). Dr. C.R. Stelck has, furthermore, brought to the writer's attention a 2-foot-long Santonian *Inoceramus* ex gr. *cardissoides-pinniformis* preserved in the Geological Museum of the University of Alberta, Edmonton. This specimen was found on Redstone River and is presumed to have been collected from the East Fork shale because of its clay ironstone matrix. These data confirm the earlier suggestions of the equivalence of the Kotaneelee Formation to the marine shale of East Fork Formation of the Mackenzie Valley (Stott, 1960, p. 19 and unpublished fossil reports of the writer) and indicate the flooding of most or all of the Liard River-Mackenzie Mountains area of the Mackenzie Salient at least in the early and mid-Santonian (Fig. 14).

Large erosional bodies of ?Coniacian to lower Campanian organic shale ("brown beds") were recently discovered on the Canadian Arctic Plain between Franklin Bay and Mackenzie River Delta (Mackay, 1958, p. 21; D.A. Russell, 1967, pp. 23, 24; Jeletzky, 1960, p. 23, corr. chart; 1968a, p. 43). *Ostrea congesta* Conrad and large flat inocerami found by Dr. D.A. Russell in the lower part of "brown beds" are somewhat suggestive of their older Santonian or Coniacian age, even though *O. congesta* may range from the late Turonian to the late Santonian (Cobban and Reeside, 1952, pp. 1018-1019). However, the vertebrates mostly found at a higher level indicate a lower Campanian age. *Inoceramus* of the *I. lobatus-cardissoides-steenstrupi* species group found by Dr. Ross Mackay at different localities in an undetermined part of the same unit indicate a mid-Santonian to early lower Campanian age, more likely the *Desmoscaphites* spp. zone (Jeletzky, 1968a, p. 43). Regardless of the exact age limits of these argillaceous beds, their presence within a tectonically positive structural element [northern slope of Aklavik Arch of Jeletzky (1961b, pp. 538, 539, 577, 578, Figs. 22, 24)] gives an additional support to the hypothesis of a submergence of most or all of the Mackenzie Mountains and Plains in the Santonian and ?Coniacian.

The regional considerations, the exclusively argillaceous lithology of the Upper Cretaceous shale division, and the presence of latest Turonian fossils 200 to 250 feet below its visible top, suggest the presence of the open sea sediments of the Coniacian, Santonian and lower Campanian in Richardson Mountains (Jeletzky, 1960, p. 23). Poor fossils suggestive of the early Coniacian (*Inoceramus* ex gr. *lamarcki-inconstans*; GSC loc. 55187, 39462) and better preserved Santonian to early lower Campanian fossils (*Inoceramus* ex gr. *lobatus* Goldfuss and *Pteria* cf. *nebrascana* Evans and Shumard) have been found by geologists of oil companies on Porcupine River between Driftwood River and Old Crow Village in shales of Eagle Plain Formation. This admittedly scant evidence suggests the flooding of the Porcupine and Eagle Plains by the Coniacian to mid-Santonian sea (Fig. 14).

The presence of apparently nonmarine mid- to late Cretaceous to Tertiary Monster and Bonnet Plume Formations (Mountjoy, 1967, pp. 4, 5, 11, 12, Fig. 1) in southern Richardson and western Ogilvie Mountains does not necessarily define the southern shore of the Richardson Mountain-Porcupine Plain basin in Coniacian to mid-Santonian time. As pointed out by Mountjoy (1967, pp. 5, 12, Fig. 2) these units appear to be largely or entirely younger than the Eagle Plain Formation and are probably products of a mid-Upper Cretaceous orogeny which flexed and uplifted the Richardson Mountains. They appear, therefore, to be post-mid-Santonian deposits correlative with the lithologically and structurally similar Wapiti Formation of the Liard River drainage area (Stott, 1960, p. 19). The writer suggests accordingly that the Coniacian to mid-Santonian sea may have reached the line approximately defined by the 65-degree latitude at the Alaska-Yukon boundary, Keno Hill and Bonnet Plume Lake (Fig. 14) at least at the time of its maximum transgression.

The Coniacian to mid-Santonian sea covered most of the western and northern parts of the Canadian Arctic Archipelago. This is indicated by the areal distribution of marine shales of the upper part of Kanguk Formation, which is known to include beds of early Santonian, mid-Santonian and late Santonian and/or early lower Campanian age (Tozer, *in* Fortier *et al.*, 1963, pp. 91-92; Tozer, 1963, pp. 28-29; Tozer and Thorsteinsson, 1964, pp. 162-165; Petryk, 1966, p. 5; unpublished fossil reports of the writer, and personal communications of E.T. Tozer).

All Santonian fossils known from the Kanguk Formation [e.g. *Inoceramus coulthardi* McLearn, *Scaphites depressus* Reeside, *Scaphites* (*Clioscaphites*) cf. *montanensis* Cobban and *Inoceramus* of the *I. lobatus-cardissoides-steenstrupi* species group (unpublished fossil reports of the writer)] are specifically identical with those of the contemporary beds of the Canadian Western Interior Basin. Most of these forms are native to the mid-continental sea of North America and do not penetrate into the Tethyan sea of the Gulf Coast. This indicates the existence of a wide seaway connecting the Santonian sea of Sverdrup Basin with those of the Canadian Western Interior Region and northern Alaska (Fig. 14). The probable position of the western shoreline of this seaway was already discussed. Judging by the presence of the Santonian and ?early lower Campanian "brown beds" near Traill Point on the western shore of Franklin Bay (Mackay, 1958, pp. 21, 24, Fig. 5) and the presence of poorly dated, marine Cretaceous rocks in Darnley Bay the north-trending eastern shoreline of this Coniacian to mid-Santonian seaway was situated between Great Bear Lake and Coppermine River (Fig. 14).

The existence of a Coniacian to mid-Santonian seaway connecting the Canadian Western Interior Basin with that of Disco Bay area, West Greenland is indicated by the already mentioned extremely strong affinities of all Coniacian to mid-Santonian ammonite and inocerami faunas of these basins (*see* above and in Birkelund, 1965, pp. 158-160, Table 2). For reasons given in connection with the discussion of the late Turonian paleogeography, the writer favours a marine connection extending across the northern part of the Canadian Arctic Archipelago, across the southern part of Ellesmere Island, and beneath Baffin Bay (Fig. 14). The widespread presence and transgressive character of marine shales of the Kanguk Formation in the northern part of Canadian Arctic Archipelago, and the affinities of their Santonian ammonites and inocerami, strongly support this working hypothesis for Coniacian-mid-Santonian time, even though it is impossible to rule out the previously mentioned alternative hypothesis of Rosenkrantz *et al.* (1942).

The already-mentioned (pp. 56, 57) extremely strong development and duration of the White Speckled Shale facies in the Boyne Member in eastern Manitoba suggests that these easternmost outcrops of Coniacian to mid-Santonian rocks represent the central rather than the eastern part of the Canadian Western Interior Basin of that time. It is concluded therefrom that the eastern shore of the Coniacian to mid-Santonian sea was situated far to the east. At the peak of the Coniacian to mid-Santonian transgression the sea may have reached a line just west of Port Arthur-Cape Tatnam and covered considerable parts of Hudson Bay and District of Keewatin (Fig. 14).

Late Santonian

The late Santonian paleogeography differs from that of the Coniacian to mid-Santonian in the occurrence of a limited transgression of the North Pacific sea (Fig. 15). This sea covered a considerable part of southeastern Vancouver Island and the Gulf Islands but apparently failed to advance north beyond Oyster River area (Sutherland Brown, 1966, Fig. 6-7) and east beyond Texada Island (Muller and Jeletzky, 1970).

All data available (Jeletzky, 1969, pp. 127, 131-133; 1970d) indicate that the Santonian sea did not cover any part of northern Vancouver Island and it appears probable that this sea reached the depressed area of southeastern Vancouver Island and Georgia Strait via the present Juan de Fuca Strait (Fig. 15). It is possible, however, that most or all of the southwestern part of Vancouver Island (i.e. between Victoria and Alberni Inlet) was originally covered by the late Santonian sea.

The presence of a late Santonian sea on Queen Charlotte Islands may be assumed for the samé reasons as the presence of the Coniacian to mid-Santonian sea.

The late Santonian invertebrate fauna of the North Pacific (i.e. Nanaimo) sea of Vancouver Island has nothing in common with the contemporary Boreal sea of the Canadian Western Interior Region (Jeletzky, 1967a, p. 70; Muller and Jeletzky, 1967, Table 1). Furthermore it has no known affinities with the late Santonian Boreal fauna of West Greenland (Birkelund, 1965, p. 166, Table 3). This suggests that the postulated seaway connecting the West Greenland Boreal Basin with the North Pacific basins of southeastern Alaska and Vancouver Island opened up sometime in the early Campanian.

In contrast to the transgressive North Pacific sea of the Insular Belt of the Canadian Western Cordillera the late Santonian Boreal seas of the Canadian Western Interior exhibit the first signs of the widespread Campanian-Maestrichtian regression. This opposition of the directions of tectonic movements in the Western Cordilleran Geosynclinal Belt and in the sedimentary basins of Western Canada is a throwback to the previously described Berriasian-Aptian pattern.

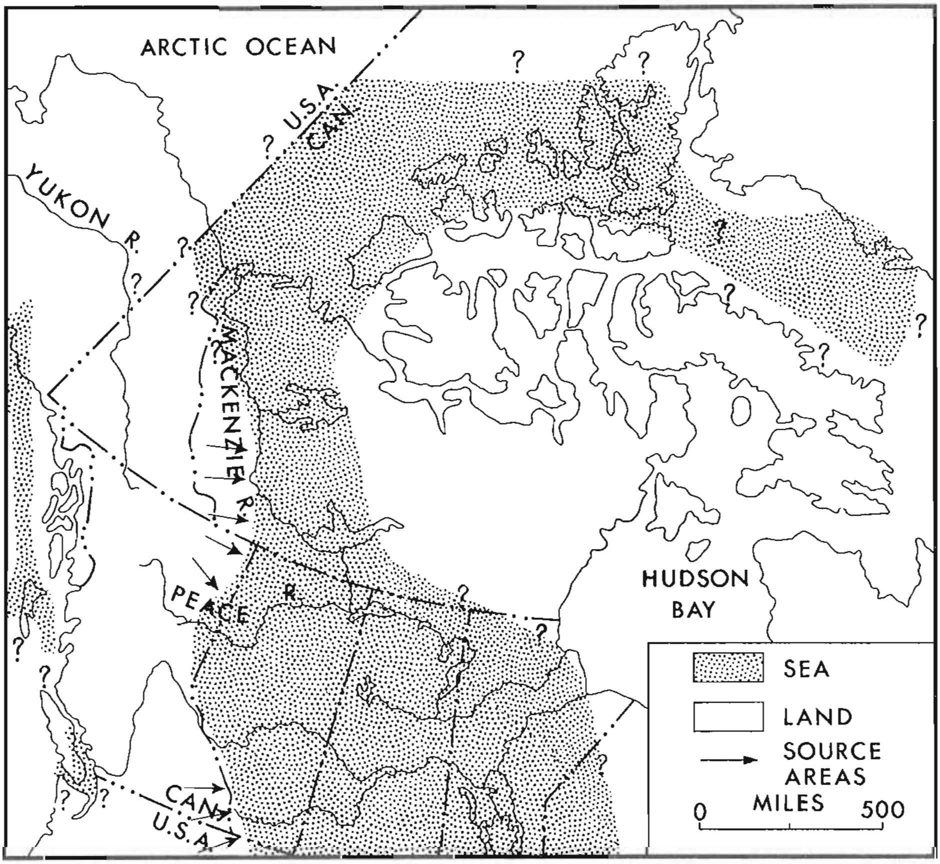

Figure 15. Late Santonian paleogeography (*Desmoscaphites* spp. time in the North American Boreal basins and *Inoceramus naumanni* time in the North Pacific basins). The map shows the inferred maximum extent of late Santonian seas.

So far as known, the late Santonian paleogeography of the Canadian Western Interior Region differs mainly from the previously discussed Coniacian to mid-Santonian paleogeography of the same region in a moderately regressive behaviour of the sea on the western side of the basin.

As pointed out by Stott (1963, pp. 109, 151; 1967b, pp. 57, 60, Fig. 13) the late Santonian regression is evident all along the Foothills Belt. It is most pronounced south of Bow River where the shale of the latest Santonian Hanson Member (upper part of *Desmoscaphites* spp. zone; Stott, 1967b, p. 56) becomes sandier and then grades laterally southwards into the partly nonmarine sandstones and siltstones of the Chungo Member (Stott, 1963, pp. 103, 109, 110, Fig. 14; 1967b, p. 57, Fig. 13). In more northerly areas of the Foothills Belt the contact of Hanson shale with Chungo sandstone occurs at progressively higher stratigraphic levels (Stott, 1963, 1967b). This indicates that the late Santonian regression was caused by uplifts which began south of of the International Boundary and gradually spread northward. This idea is reflected in Figure 15.

The apparent absence of the late Santonian marine faunas in the Kotaneelee Formation of Liard River drainage area (Stott, 1960, pp. 18, 19) and the gradational superposition of nonmarine Wapiti Formation on the Kotaneelee shale (McLearn and Kindle, 1950; Williams and Burk, Jr., 1964, p. 182) suggest the complete withdrawal of the late Santonian sea from the Liard River-Mackenzie Mountain Region on the southern side of Mackenzie Salient (Fig. 15). Some facies changes recorded by Stott (1967b, p. 58, Fig. 13) in the Chungo Member of Dawson Creek area suggest, in the writer's opinion, that the northwestern shoreline of the late Santonian sea was situated closely north of Peace River (Fig. 15).

In spite of the scarcity and inconclusive character of data presented by Mountjoy (1967, pp. 5, 12), it seems likely that the late Santonian regression also affected the northern side of the Mackenzie Salient and caused a retreat of the sea from southern Richardson Mountains, Eagle Plains, and southwestern Porcupine Plains (Fig. 15).

This areally limited late Santonian regression is important in marking a turning point in the late Lower to late Cretaceous history of the Canadian Western Interior Region, consisting of a permanent reversal of the tectonic behaviour of the region, which had been dominated by subsidence and progressively larger Cretaceous transgressions since the early Albian time. As will be shown, the relatively weak tectonic pulse that caused the late Santonian regression was only the first in a series of ever stronger pulses which affected at intervals the western sides of the late Cretaceous basins of the Canadian Western Interior Region causing a progressive retreat to the east of its Campanian and Maestrichtian seas. These positive tectonic movements apparently culminated in the permanent uplift of entire basin above sea level late in the Maestrichtian or (?)very early in the Paleocene (Danian time).

So far as known, the late Santonian regression did not affect any part of the Canadian Arctic Archipelago and its late Santonian paleogeography is believed to be identical to that of the mid-Santonian (Figs. 14, 15). The affinities of late Santonian ammonite and inocerami fauna of West Greenland with their Canadian and American Western Interior counterparts are just as close as those of the Coniacian to mid-Santonian faunas (Birkelund, 1965, p. 166, Table 3). This indicates the persistence into the late Santonian of the Ellesmere Island Strait connecting these basins.

The presence of late Santonian beds in the upper part of the White Speckled Shale (Boyne Member) in eastern Manitoba is indicated by the early Campanian age of its uppermost beds (*see* p. 56). Therefore the Eastern Great Plains were far removed from the eastern shore of the basin in late Santonian times. However, a minor westward retreat of the eastern shoreline of the late Santonian sea is assumed to have taken place because of the generally regressive conditions elsewhere in the southern part of the Canadian Western Interior Basin of that time (Fig. 15).

Early Campanian

The early Campanian paleogeography depicted in Figure 16 is closely similar to the late Santonian paleogeography.

In the early lower Campanian (≈*Pachydiscus haradai* time; Muller and Jeletzky, 1967) the North Pacific sea of southeastern Vancouver Island is not known to have spread appreciably anywhere and had retreated southwards in the Comox area (Jeletzky, 1970d; Fig. 16). The advance of the early lower Campanian sea of Queen Charlotte Islands into the southern part of Moresby Island is inferred from the presence of the early upper Campanian sea (early *Hoplitoplacenticeras vancouverense* time) on the northern end of Vancouver Island (Fig. 17).

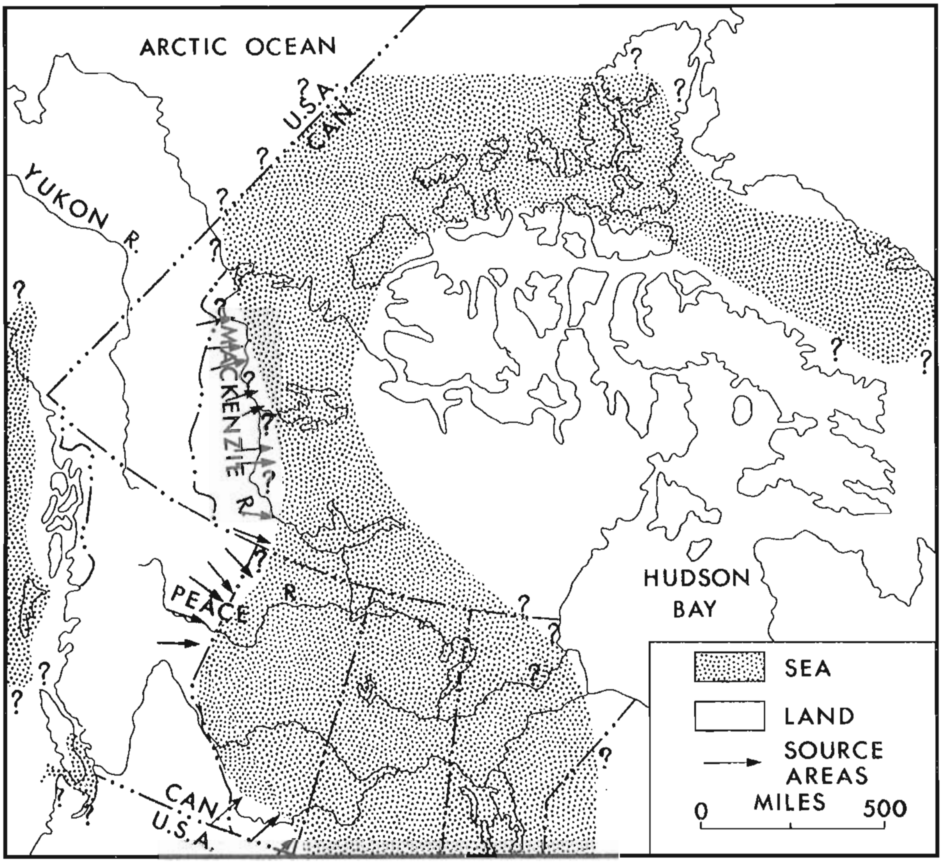

Figure 16. Early Campanian paleogeography (lower Lea Park or *Hoploscaphites hippocrepis* time in the North American Boreal Province and *Pachydiscus haradai* time in the North Pacific Province). The map shows the maximum extent of lower Campanian seas.

The late lower Campanian (*Inoceramus schmidti* time) sea of southeastern Vancouver Island advanced eastward beyond Texada Island and flooded a limited area of present Coast Mountains north of Vancouver (Mathews, 1958; Sutherland Brown, 1966, Fig. 6-7). No paleogeographical map was drawn for late lower Campanian time as the extent and outline of the *Inoceramus schmidti* sea are believed to be similar to those of the early and mid-upper Campanian seas shown in Figures 17 and 18.

The early Campanian paleogeography of the Boreal Basin of the Canadian Western Interior Region is characterized first of all by strong but apparently localized uplifts on its western side representing the continuation and expansion of weaker and more localized late Santonian uplifts. These uplifts resulted in a limited eastward retreat of the early Campanian sea from Southern Foothills and Southern Alberta Plains and the formation of an extensive deltaic apron of Milk River Delta in that area (L.S. Russell, 1939, pp. 84-85, Fig. 2; Williams and Burk, Jr., 1964, Fig. 12-18). Generally speaking the lower Campanian rocks of the Canadian Great Plains exhibit two sharply opposed facies. In Manitoba, and in Saskatchewan east of the 106 degrees west they consist of marine shales and are often represented by the White Speckled shale. In Manitoba and southeastern Saskatchewan this facies comprises the upper part of the Boyne Member of the Vermilion Formation. Farther west the corresponding time interval is represented by the *Hoploscaphites hippocrepis* and *Haresiceras* cf. *montanense*-bearing lower part of the Lea Park Formation (Jeletzky, 1968a, p. 44 and in the next paragraph).

A regional hiatus comprising most or all of the early Campanian (i.e. *Hoploscaphites hippocrepis* time) is traditionally assumed to occur between the Pembina and Boyne Members of the Vermilion River Formation in southern Manitoba and Saskatchewan (e.g. L.S. Russell and Landes, 1940, p. 183; Cobban and Reeside, 1952, corr. chart; Williams and Burk, Jr., 1964, p. 173, Fig. 12-18). As pointed out by Jeletzky (1968a, p. 44) this assumption is invalidated by the discovery of *Hoploscaphites hippocrepis* fauna in several areas of the Great Plain Region. As now known (p. 56), this fauna is present also in the upper part of Boyne Member.

The White Speckled shale lithology of *Hoploscaphites hippocrepis* zone in eastern Manitoba indicates that this area represented the central part of the basin in early Campanian time just as it did throughout Coniacian and Santonian time (Fig. 16).

The complete absence of an erosional interval at the Santonian-Campanian boundary and the persistence of the White Speckled shale facies into the lower Campanian of Manitoba and eastern Saskatchewan suggest that the eastern margin of the Canadian Western Interior Basin was not appreciably affected by the Santonian and early lower Campanian uplifts, which were so prominent along its western margin. Only a minor regression of the early lower Campanian sea is therefore assumed to have taken place in the east (Fig. 16).

The lower Campanian part of the Lea Park shale begins to interfinger with the sandstone tongues of Milk River Formation in the southwesternmost part of Saskatchewan (Williams and Burk, Jr., 1964, p. 173, Fig. 12-3). These sandstone tongues, which are predominantly marine in their eastern parts, thicken southwestwards at the expense of shale and grade into the nonmarine rocks of the Milk River Formation proper (L.S. Russell, 1939, p. 86, Fig. 2; L.S. Russell and Landes, 1940; Williams and Burk, Jr., 1964, pp. 173, 188, Figs. 12-3, 12-8; this paper Fig. 16).

The Milk River shoreline is much farther east in Southern Foothills and adjacent parts of southern Alberta Plains than the contemporary Chungo shoreline in more northerly areas of the Foothills Belt (Tovell, 1958; Stott, 1963, 1967b; Williams and Burk, Jr., 1964, p. 188, Fig. 12-18). This fact and the previously mentioned gradual rise of the Hanson-Chungo contact toward the north (p. 61) indicate that the retreat of the early lower Campanian sea began in the south and only gradually progressed northwards. This necessitates a reduction of the extent of the Milk River Delta shown in L.S. Russell's (1939, Fig. 2) map. The predominantly marine character of Chungo sandstone in the more northerly part of the Southern Foothills, throughout the Central Foothills, and in southern parts of Northern Foothills (Stott, 1963, pp. 105, 108, 112; 1967b, p. 57) indicates that the lower Campanian (i.e. *Hoploscaphites hippocrepis* or lower Lea Park) sea lingered within the greater part of the Foothills Belt, while the nonmarine Milk River sandstone was being deposited in the southeasternmost part of this belt. This embayment of the early lower Campanian sea is shown in Figure 16.

On Mistanusk Creek in Peace River Foothills (Stott, 1967b, p. 58): "carbonaceous sediments above the Chungo sandstone are not overlain by any younger marine shale but are continuous with the thick succession of continental sediments of the Wapiti Formation (Pl. XVII). It is probable that some of these nonmarine beds are equivalent to the marine shales of the type Nomad Member and some could be equivalent to upper beds of the type Chungo Member." These northward facies changes of the uppermost beds of the Wapiabi Formation and the suggested lowering of the lower boundary of nonmarine beds of the Wapiti Formation in this direction indicate the occurrence of a lower Campanian uplift north and northwest of the erosional edge of Chungo sandstone

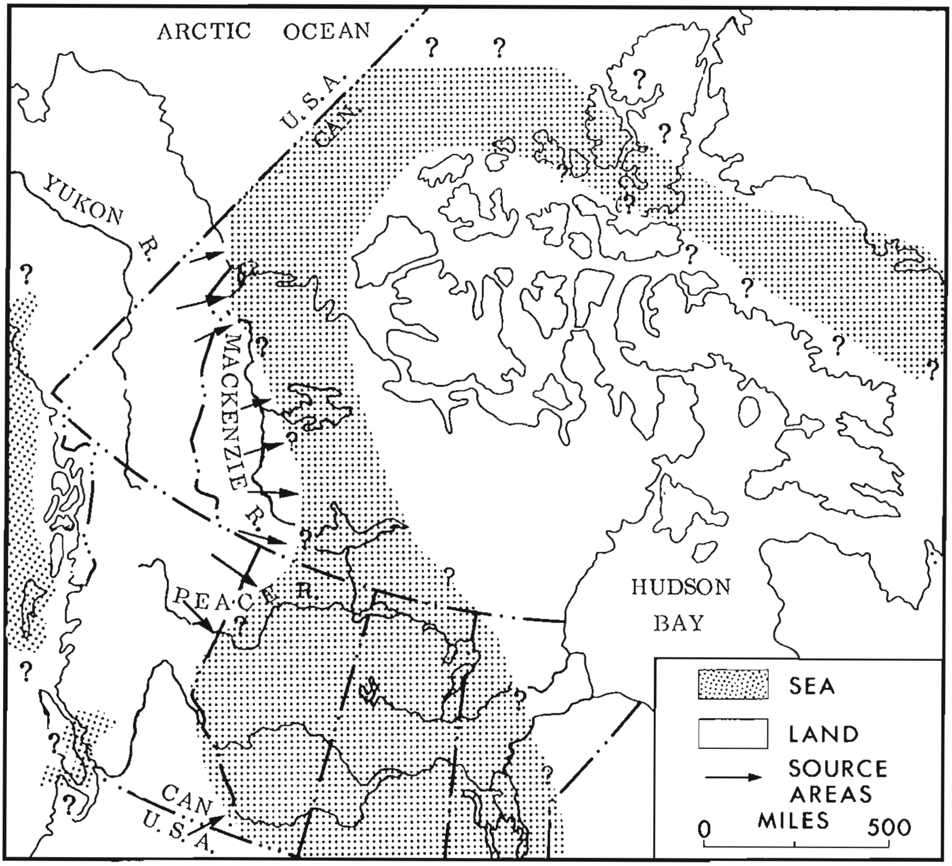

Figure 17. Early upper Campanian paleogeography (Pakowki or early *Baculites obtusus* time in the North American Boreal basins and early *Hoplitoplacenticeras vancouverense* time in the North Pacific basins). The map shows the inferred maximum extent of the early upper Campanian seas.

(i.e. on the northern part of the embayment of Chungo sea). This uplift, which apparently began within the Mackenzie Salient, and gradually spread southwards, must have been responsible for the gradual southward and southeastward retreat of the lower Campanian sea and a progressive narrowing of its embayment within the eastern zone of the Foothills Belt shown in Figure 16.

No marine or nonmarine lower Campanian rocks are known in that vast part of the Canadian Western Interior Region situated between the Liard River-Lower Athabasca River area in the south, Richardson Mountains in the west, Canadian Shield in the east, and the Arctic Coastal Plain in the north.

Farther north the presence of the marine lower Campanian rocks was recently proven by the discovery of several vertebrates diagnostic of the upper Niobrara and lower Pierre of the Western Interior Region of the United States (D.A. Russell, 1967, pp. 36-37). These fossils occur in the ?Coniacian to lower Campanian "brown beds" which are widespread on the Arctic Coastal Plain between the Mackenzie River Valley and Darnely Bay area (*see* pp. 58, 59).

The presence of lower Campanian rocks in the upper part of the Kanguk Formation of the Sverdrup Basin is probable but not proven. This formation is locally rich in the Santonian and/or early Campanian *Inoceramus* of the *I. lobatus-cardissoides-steenstrupi* species group (*see* pp. 58, 59) but did not yield any diagnostic lower Campanian fossils.

The apparent absence of lower Campanian marine fossils and the generally regressive conditions prevalent in the early Campanian time farther south resulted in a traditional assumption of a complete emergence of the northern part of the Western Interior Region at that time (e.g. L.S. Russell, 1939, p. 86, Figs. 2-4; Williams and Burk, Jr., 1964, p. 188, Figs. 12-18, 12-19, 12-20; Warren and Stelck, unpublished manuscript).

The writer (Jeletzky, 1950, p. 23) objected to this conclusion because of rather close affinities of the Boreal lower Campanian marine faunas of midcontinental seas of North America with those of West Greenland, northern Siberia, and the Urals. His conclusion about the existence of a northern outlet of the early Campanian sea of the Canadian Western Interior Region was subsequently confirmed by the already mentioned strong upper Niobrara-lower Pierre affinities of the marine vertebrate fauna found in the lower Campanian beds ("brown beds") of the Arctic Coastal Plain (D.A. Russell, 1967, pp. 36, 37) and by the strong Western Interior affinites of the lower Campanian ammonite fauna (especially the presence of *Haresiceras* sp.) of West Greenland (Birkelund, 1965, p. 166, Table 3). It is concluded, therefore, that a fairly broad and deep early Campanian seaway persisted on the eastern side of Mackenzie Valley. This seaway connected the Lea Park sea of the lower Athabasca River area with the early Campanian sea of the Sverdrup Basin via the Anderson River area of Arctic Coastal Plain (Figs. 16-18). As in late Turonian and Santonian, the marine connection with the Disco Bay area of West Greenland was apparently maintained via a seaway crossing the southern Ellesmere Island and Baffin Bay area.

The already mentioned Monster and Bonnet Plume Formations of southern Richardson and western Ogilvie Mountains (Mountjoy, 1967, pp. 4, 11, 12, Fig. 2) are believed to be equivalents of the Belly River Group of the Foothills and Great Plains Regions. Therefore, their lower parts are assumed to be of a lower Campanian age. The nonmarine nature of these units suggests that the areas of the present Wernecke, Ogilvie and southern Richardson Mountains were completely emergent in the early Campanian. The same is believed to be true of the Eagle and Porcupine Plains, adjacent parts of the Coastal Plain, and part or all of the Richardson Mountains (Fig. 16) because of the presence of apparently equivalent nonmarine rocks of Moose Channel Formation at the western margin of Mackenzie Delta northwest of Aklavik (Mountjoy, 1967, pp. 8-9, Fig. 2).

Late Campanian and Maestrichtian

A considerable diversity of the physiography and far-reaching changes of paleogeographical pattern in the late Campanian and Maestrichtian have necessitated their presentation in four paleogeographical maps (Figs. 17-20).

Western Cordillera. So far as known, the late Campanian North Pacific seas continued to advance throughout the Canadian Western Cordillera in contrast to their predominantly retreating Boreal counterparts of the midcontinental region. They began to retreat locally in the early lower Maestrichtian and presumably receded beyond the western continental margin before the end of the early Maestrichtian.

A limited late Campanian transgression representing *Hoplitoplacenticeras vancouverense* and *Metaplacenticeras* cf. *pacificum* zones (Fig. 3) flooded the northern part of Vancouver Island and some islands in the

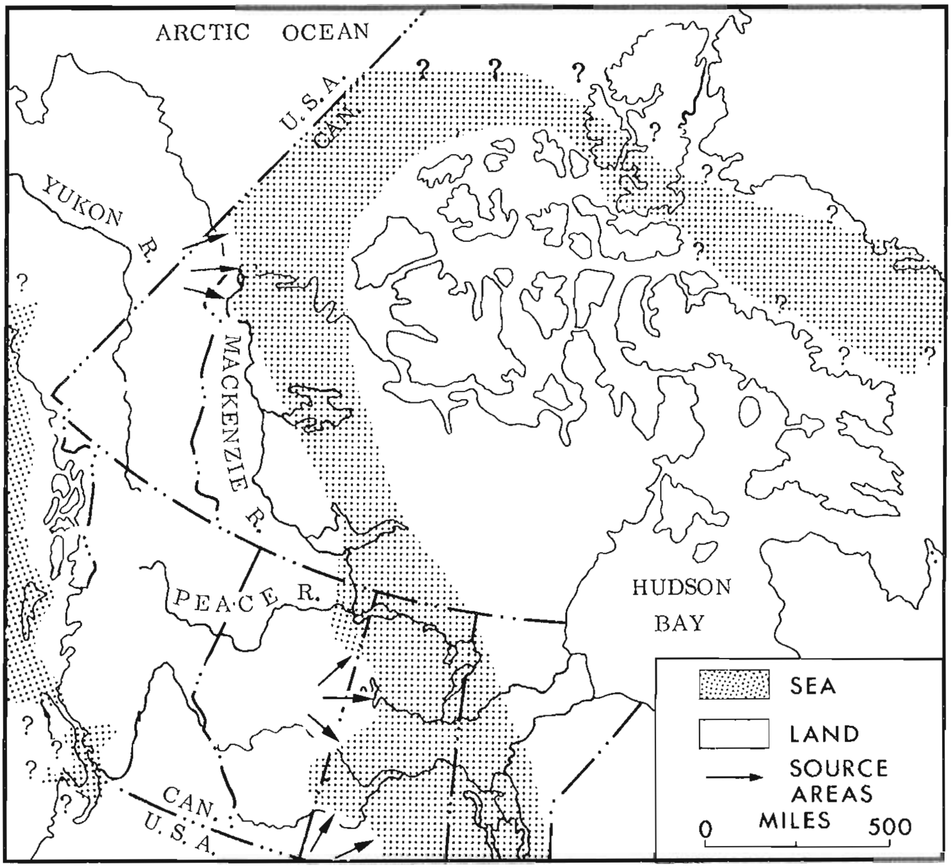

Figure 18. Mid- upper Campanian paleogeography (late Belly River or *Hoploscaphites gilli* time in the North American Boreal basins; late *Hoplitoplacenticeras vancouverense* time in the North Pacific basins). The map shows the inferred maximum extent of mid- upper Campanian (Belly River) regression in the Western Interior Region.

Queen Charlotte Strait farther to the north (Jeletzky, 1969, pp. 127, 131-133). This area was apparently above sea level throughout the earlier Upper Cretaceous. So far as known, the late Campanian sea invaded this area from the northwest and/or ?west. This circumstance and the general Cretaceous age (Sutherland Brown, 1968, p. 104) of the predominantly marine Skidegate Formation of Queen Charlotte Islands suggest that the upper Campanian embayment of northern Vancouver Island was directly connected with the upper Campanian sea that is believed to have covered Queen Charlotte Islands (Figs. 17 to 19).

The facies pattern and the inferred direction of paleoslope suggest that the late Campanian sea of northern Vancouver Island did not penetrate south of the line defined by Kwakiutl Point-head of Neroutsos Inlet and Port McNeill (Jeletzky, 1970d and unpublished). The position of eastern shoreline of this embayment is somewhat uncertain because of an apparent lack of Cretaceous outcrops east of the line: eastern side of Hope Island-Port Hardy-Port McNeill. The interfingering of neritic littoral and nonmarine facies in these late Campanian outcrop-areas and the inferred northwestern and/or ?western origin of the transgression suggest that the sea did not penetrate far beyond its presently known easternmost outcrops. The eastern margin of this embayment shown in Figures 17 to 19 may have been placed too far east.

There are no indications of the presence of marine early Maestrichtian rocks anywhere on the northern part of Vancouver Island (Jeletzky, 1970d) and it is assumed tentatively that the Nanaimo sea retreated from this embayment prior to the end of the *Metaplacenticeras* cf. *pacificum* time (Fig. 20).

It is suggested tentatively that the Skidegate Formation of Queen Charlotte Islands includes some marine early lower Maestrichtian rocks (Fig. 20).

The southern embayment of the Nanaimo sea continued to be flooded throughout the late Campanian and early lower Maestrichtian. The presence of a considerable thickness of marine shales in the sections of Garibaldi Park area of Coast Mountains above the *Inoceramus schmidti*-bearing beds (Mathews, 1958) suggests that this area formed part of the southern marine embayment of Nanaimo sea in the late Campanian and Maestrichtian (Figs. 17-20). This conclusion is supported by the apparent presence of early lower Maestrichtian shales with *Baculites occidentalis* Meek sensu Usher and *Pachydiscus* cf. *egertoni* Forbes (unpublished fossil reports of the writer) as far east as Texada Island. This suggests that there was no early lower Maestrichtian (*Nostoceras hornbyense* time) regression of the Nanaimo sea in its southern embayment.

The writer agrees with Sutherland Brown (1966, Fig. 6-7) that the northern and southern embayments of Nanaimo sea on Vancouver Island were separated by an isthmus until the final withdrawal of the sea beyond the western continental margin sometimes in the early Maestrichtian (Figs. 19, 20).

Southern Part of Western Interior Region. Throughout the Foothills Belt the deposition of the nonmarine Milk River wedge as well as that of its marine (Chungo Member) and nonmarine equivalents was terminated by a fairly extensive but brief westward transgression of the early upper Campanian sea (*Baculites obtusus* time). This sea deposited a widespread marine shale unit locally called Claggett, Pakowki, and Nomad (Fig. 17).

According to L.S. Russell (1939, p. 86, Fig. 3) the Pakowki transgression just reached the southernmost part of the Canadian Foothills. The more recent recognition of the Pakowki age of the Nomad shale and its continuity with the Pakowki shale proper (Tovell, 1956; Wall and Germundson, 1963, pp. 343, 345; Stott, 1963, pp. 114, 118-119; 1967b, pp. 61-62) reveals that the Pakowki transgression reached the more northerly parts of the Southern Foothills, all of the Central Foothills, and that part of the Northern Foothills situated south of Mistanusk Creek. As pointed out by Stott (1967b, p. 62): "As the member is not present at Mistanusk Creek, the sea apparently did not advance as far westwards as the present Foothills region of British Columbia. The occurrence of carbonaceous sediments above the Chungo sandstone on Mistanusk Creek suggests that deposition in that area may have been continuous but was in a continental environment. It seems probable that the shoreline lay between these Foothills and the marine shales found on lower Smoky River. The shoreline of the Nomad (i.e. Pakowki; writer's remark) sea must have had a northerly trend between upper Smoky and Wapiti River. The absence of these shales in northeastern British Columbia suggests that uplift of the source area was somewhat more pronounced than farther south."

The lateral replacement of Pakowki (= Nomad) shale by nonmarine beds of lower Belly River and lower Wapiti Formations in the southernmost and northernmost parts of the Foothills Belt suggests that the Pakowki sea formed a westward convex embayment confined between the two eastward-protruding areas of the shoreline. It was similar to but considerably larger than the maximum embayment of Milk River (= Chungo) time (Figs. 16, 17). The fringing promontory-like land areas are usually interpreted as large deltas debouching into the Pakowki sea.

The transgression of the Pakowki sea was terminated by a strong mid-upper Campanian tectonic pulse which elevated the whole length of the western shoreline of the basin, produced an abundance of arenaceous to psephitic clastic material, and caused a retreat of the contemporary (late Lea Park) sea to the central and eastern parts of the Great Plain Region (Fig. 18). The nonmarine clastics produced by this mid-upper Campanian uplift (time of *Hoploscaphites gilli*; *see* Fig. 3) constitute most of Belly River Formation proper and its equivalents farther north (e.g. some lower part of Brazeau Formation, middle? part of Wapiti Formation). These nonmarine clastic wedges extend as far east as the Alberta-Saskatchewan border over the most of the Great Plain Region, forming a southern lobe which can be named the Southern Delta and a northern lobe which can be named the Northern Delta (Fig. 18). The late Lea Park sea (*Hoploscaphites gilli* time) formed a westward convex embayment between these deltaic lobes. The embayment formed by late Lea Park sea was shaped like that of the preceding Pakowki sea but situated considerably farther east.

Deposition of noncalcareous, marine shales continued throughout upper early and mid-upper Campanian time in Manitoba and eastern Saskatchewan. The Pembina Member of the Vermilion River Formation appears to be a time-equivalent of the Pakowki shale of more westerly areas. This is indicated by the previously discussed equivalence of the Chungo Member, Milk River Formation and lower Lea Park Formation to the underlying Boyne Member and the presence of *Hoploscaphites gilli* fauna in the upper part of the Lea Park Formation and in the basal part of the overlying Riding Mountain Formation (Cobban and Jeletzky, 1965).

Beginning at about 104 degrees west the shales of Pembina-basal Riding Mountain become largely replaced by the equivalent mostly light grey shales of the upper Lea Park Formation carrying *Hoploscaphites gilli* fauna (unpublished intradepartmental reports of the writer). In this area the Lea Park Formation begins to be capped by a marine sandstone representing the pinch-out of the Belly River Formation (Williams and Burk, Jr., 1964, p. 173, Fig. 12-3). Still farther west, southwest, and northwest, the upper Lea Park shales become interbedded with progressively greater thicknesses of sandstone. The sandstone wedges are predominantly marine in their eastern parts, thicken westwards at the expense of shales and finally merge into nonmarine clastics of the Belly River Formation (L.S. Russell, 1939; L.S. Russell and Landes, 1940; Williams and Burk, Jr., 1964, pp. 173, 188, Figs. 12-3, 12-19, 12-20).

The essential contemporaneity of the upper Lea Park shale and intertongued marine sandstones of the Belly River is indicated by the find of *Hoploscaphites gilli* in the Grizzly Bear shale member in Vera Potash Shaft, western Saskatchewan (Cobban and Jeletzky, 1965, p. 795, GSC loc. 21146)[1].

There is little doubt that the mostly light grey Lea Park (= La Biche) shale of the lower Athabasca River area includes the open sea facies of most or all of the Pakowki and Belly River Formations in addition to the previously mentioned lower Campanian *Hoploscaphites hippocrepis* zone

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[1] As pointed out by Dr. R.T.D. Wickenden of the Geological Survey of Canada (written comm., October 25, 1965): "It is noted that the location given on the map (i.e. Cobban and Jeletzky's, 1965, Fig. 1; writer's remark) is incorrect by about 180 miles. The correct location is section 24, Township 41, Range 24 west of 3rd Meridian, about Long. 109°22', Lat. 52°32'. At this locality the formation should be the Grizzly Bear marine member of the Belly River Formation according to Shaw and Harding, 1954. There is too much nonmarine sedimentation in this area to apply the term Riding Mountain Formation."

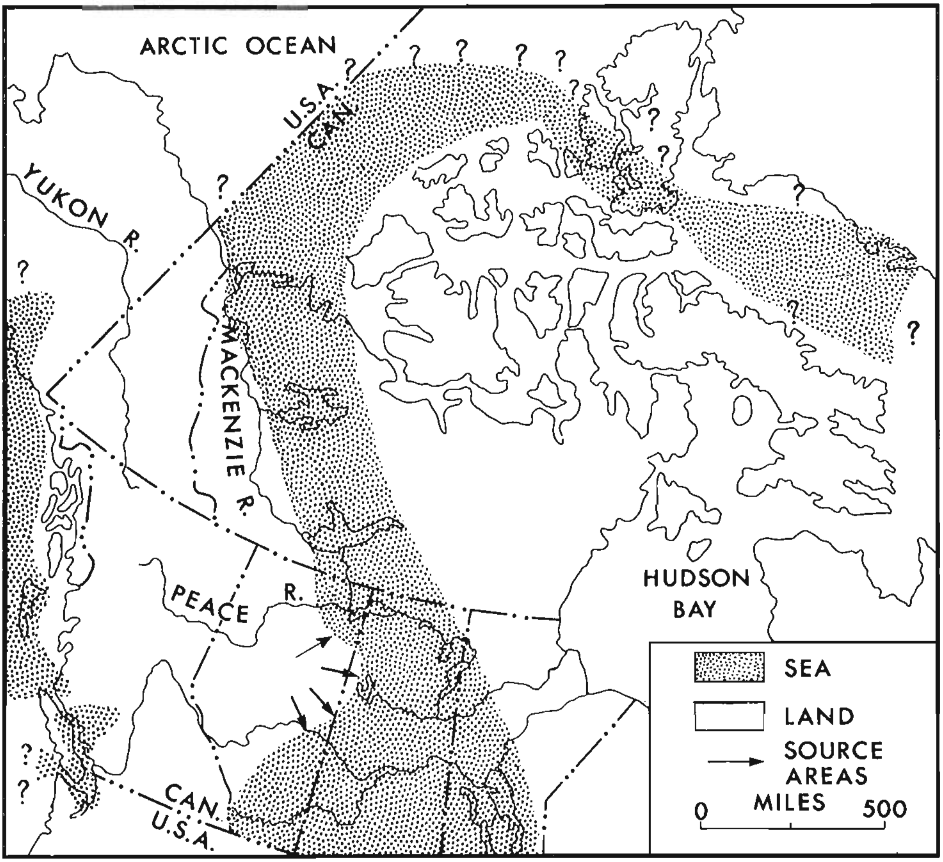

Figure 19. Late upper Campanian paleogeography (early Bearpaw or *Hoploscaphites nodosus* time in the North American Boreal basins and early *Metaplacenticeras* cf. *pacificum* time in the North Pacific basins). The map shows the inferred maximum extent of late upper Campanian seas in the Western Interior Region.

(McLearn, 1937, p. 118; Jeletzky, 1968a, pp. 43-44 and an unpublished identification of *Baculites* cf. *obtusus* Meek from the upper part of the unit). These open sea shales were apparently deposited in an embayment of the late Lea Park sea on the northeastern side of the northern Belly River Delta (Fig. 18). They are believed to pass laterally into the noncalcareous Chungo and Pakowki (= Nomad) members of the Wapiabi Formation and the overlying nonmarine clastics of the Wapiti Formation in the lower Smoky River area.

The apparently complete upward replacement of the White Speckled Shale facies by the noncalcareous shales of Pembina Member and middle to upper Lea Park Formation suggests a general shallowing of the early to mid-upper Campanian Western Interior Basin as compared with its early Campanian predecessor. This was probably caused by a corresponding westward retreat of the eastern shorelines of these basins (Figs. 17, 18) as compared with the eastern shoreline of the early Campanian (*Hoploscaphites hippocrepis* time) basin (Fig. 16).

A fairly widespread but brief Bearpaw transgression flooded the southern part of the Belly River landmass (its southern delta; Figs. 18, 19) at the onset of the late upper Campanian (in an unnamed time interval immediately preceding the *Hoploscaphites nodosus* time; Fig. 3). The brief subsidence which caused this westward transgression was largely restricted to the Southern Foothills and Plains, as the northern part of the Belly River landmass was relatively little affected by it (Figs. 18, 19).

The marine shale of the Bearpaw Formation separates the nonmarine clastics of the Belly River from those of the St. Mary River Formation over the Southern Alberta Plains and extends well into the Foothills south of Bow River (L.S. Russell, 1939; L.S. Russell and Landes, 1940, pp. 175, 186; Jeletzky, 1968a, p. 49). However, it is not known to reach the Foothills anywhere north of Bow River (Fig. 19). In this part of the Foothills the nonmarine rocks of the Belly River and Edmonton Formations are in contact and have to be differentiated on lithology alone. The same is done on the Western Plains north of Pembina River where the marine shale of Bearpaw Formation pinches out between the Belly River and Edmonton Formations with the southern part of the Northern Delta of the Belly River time (Figs. 18, 19). In most parts of this area the Northern Delta grades upward into the Edmonton Delta which then expanded through the remainder of the late upper Campanian.

As pointed out by L.S. Russell (1939, p. 90, Fig. 8) the westward advance of Bearpaw Sea was rather rapid. So far as known, the Bearpaw transgression reached its maximum extent before the beginning of *Hoploscaphites nodosus* time (Jeletzky, 1968a, p. 49). It was terminated by a regional uplift of western and northwestern sides of the basin in the early part of late upper Campanian (*Hoploscaphites nodosus* time; Fig. 3). This uplift was most pronounced on the northwestern side of the basin and so must have been caused by tectonic movements centred yet farther north in the central part of the Mackenzie Salient (Fig. 19). The uplift apparently spread gradually southward to the International Boundary, judging by the presence of *Hoploscaphites nodosus* zone in the Foothills south of Bow River and its apparently complete absence in more northerly parts of the Foothills Belt. The Bearpaw regression differs from earlier late Santonian to mid-Campanian regressions in the apparent absence of a corresponding uplift centred south of the International Boundary and gradually progressing northward. The area of southern Belly River Delta apparently re-emerged because of the gradual southward and southeastward spread of the above mentioned northern uplift (Figs. 19, 20).

The above described uplift was followed by other stronger uplifts interspersed with relatively feeble and brief, possibly localized phases of subsidence. These progressively increasing tectonic pulses were apparently all centred to the northwest and west of the basin as they have resulted in a slow and pulsating southeastward and eastward retreat of the western and northwestern shorelines of Bearpaw Sea (L.S. Russell, 1939, p. 92, Fig. 8). This retreat lasted through the late upper Campanian and a considerable part of the Maestrichtian (Jeletzky, 1968a, pp. 49-54). Its vagaries were responsible for a considerable variety of facies characteristic of the middle and late Bearpaw sea (L.S. Russell, 1950; Caldwell, 1968).

In *Baculites baculus* time the Bearpaw sea of the Southern Alberta Plains retreated to a position slightly west of the Alberta-Saskatchewan boundary. Farther north it retreated approximately to the northeast-trending line passing through Battleford and Lloydminster (Fig. 20). It seems likely that the *Baculites grandis* sea was even more restricted (Jeletzky, 1968a, p. 54).

The local presence of the Maestrichtian marine rocks younger than the *Baculites grandis* zone in southern Saskatchewan and (or?) Manitoba is suggested because of paleogeographical implications (*see* p. 74) of the extremely close affinity of the late lower and(?) early upper Maestrichtian ammonites and inocerami of the type Fox Hills Formation (Waage, 1968, pp. 143-146) with their West Greenland counterparts (Birkelund, 1965, pp. 167-168, Table 3). As yet, only the record of *Discoscaphites* cf. *nicolleti* (Morton) from the Odanah siliceous phase of Riding Mountain Formation (L.S. Russell and Landes, 1940, p. 191) can be cited in support of this hypothesis. The apparent absence of

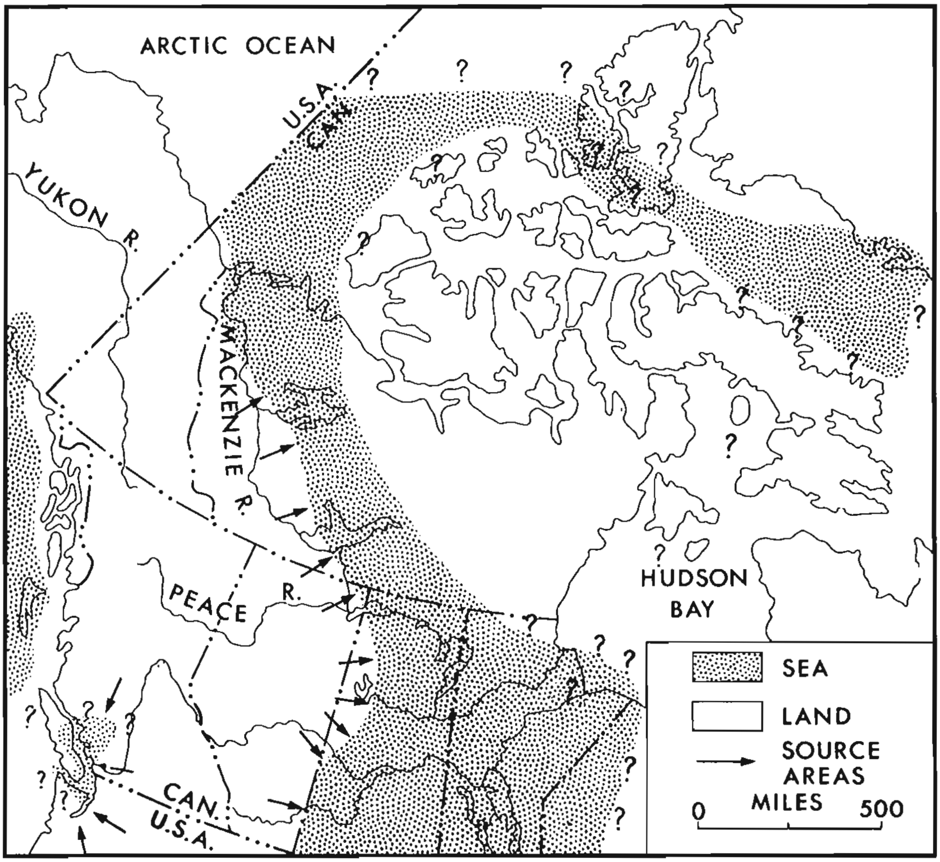

Figure 20. Early lower Maestrichtian paleogeography (*Baculites baculus* time in the North American Boreal basins and *Nostoceras hornbyense* time in the North Pacific basins). The map shows the inferred maximum extent of early lower Maestrichtian seas.

paleontological evidence is, however, not a valid counter-argument as our knowledge of the fauna of the uppermost Riding Mountain beds is negligible.

As the late upper Campanian Bearpaw Sea retreated the blanket of early Maestrichtian nonmarine rocks of the St. Mary River and Edmonton (including upper Brazeau) Formations spread eastward across the Southern Great Plains. Farther northeast the great lobe of the Edmonton Delta was spreading steadily southeastward, eastward and northeastward (Fig. 19).

In Manitoba and eastern Saskatchewan the deposition of the Riding Mountain shale continued uninterrupted through the late upper Campanian and into the Maestrichtian (Wickenden, 1945, p. 49; Jeletzky, 1968a, pp. 48-53; Williams and Burk, Jr., 1964, pp. 173-175, Fig. 12-3). The late upper Campanian part of Riding Mountain Formation merges into the Bearpaw Formation at about 104 degrees west where the thin wedge of the Belly River sandstone first appears between it and the upper Lea Park shale (Williams and Burk, Jr., 1964, p. 174, Fig. 12-3).

The shales of the upper Riding Mountain and Bearpaw formations, are dark grey, predominantly noncalcareous and locally siliceous (Odanah phase). No light grey, calcareous shales similar to those of the underlying lower Lea

Park Formation or Boyne Member are known in the late Campanian-Maestrichtian interval under the Central Great Plains. This suggests the continuation of the early to mid-upper Campanian (i.e. mid- to late Lea Park; *see* p. 70) regression on the eastern side of the Canadian Western Interior Basin in the late upper Campanian (i.e. Bearpaw) time and an appreciable westward retreat of its eastern shoreline as compared with the early to mid-upper Campanian (Fig. 19).

Northern part of Western Interior Region and Arctic Archipelago. In contrast to the abundance of detailed and relatively well-dated information pertaining to the late Campanian and Maestrichtian paleogeography of the southern part of the Canadian Western Interior Region, there is an appalling scarcity of such information pertaining to the northern part of this region and the Canadian Arctic Archipelago. This necessitated a separate summary treatment of the latter regions and caused the virtual identity of the corresponding parts of Figures 16 to 20.

So far as the writer knows, no marine or nonmarine late Campanian and Maestrichtian rocks are known in that vast part of the Canadian Western Interior Region between the Liard River-lower Athabasca River in the south, Mackenzie and Richardson Mountains in the west, Canadian Shield in the east and the Arctic Coastal Plain in the north.

The Monster and Bonnet Plume Formations of southern Richardson and western Ogilvie Mountains (Mountjoy, 1967, pp. 4, 11-12, Fig. 2) are believed to include late Campanian and Maestrichtian nonmarine beds. The same appears to be true of the Moose Channel Formation (Mountjoy, 1967, pp. 8-9, Fig. 2) exposed at the northwestern side of Mackenzie Delta. This suggests that the vast region including present Wernecke, Ogilvie and Richardson Mountains, Eagle and Porcupine Plains, and the Canadian Coastal Plain west of Mackenzie Delta was completely emergent in the late Campanian and Maestrichtian (Figs. 17-20).

Maestrichtian foraminifera were recently discovered in the "grey beds" in the Anderson River area of the Arctic Coastal Plain (T. Potter Chamney *in* D.A. Russell, 1967, pp. 25-26).

The Santonian to? lower Campanian *Inoceramus lobatus-cardissoides-patootensis* fauna ranges up into the uppermost 120 feet of the Kanguk Formation on Axel Heiberg Island (Souther, *in* Fortier *et al.*, 1963, p. 443). This leaves hardly any room for the younger Campanian or Maestrichtian faunas beneath the nonmarine clastics of the Eureka Sound Formation even in the central part of Sverdrup basin. Despite the fact that in places (e.g. on Ellef Ringnes Island, Stott, 1969, p. 28) the lithological boundary appears to be transitional, the Kanguk-Eureka Sound contact is, believed to be paraconformable and probably unconformable. Thorsteinsson and Tozer (1957, pp. 19-20), Tozer (*in* Fortier *et al.*, 1963, p. 93) and Tozer (1963, p. 30) observed a transgressive overstep of the Eureka Sound Formation on the progressively older Mesozoic and Paleozoic units in eastern Ellesmere Island implying an unconformity beneath the former.

These structural relationships and the paleobiotic evidence presented below (*see* p. 74) indicate that the late Campanian and Maestrichtian (including the Fox Hills equivalents) marine rocks corresponding to those of the Disco Bay area (Birkelund, 1965) were originally deposited at least in the axial part of the Sverdrup Basin and on the southern part of Ellesmere Island (Figs. 17-20). They must have been completely eroded away prior to the deposition of the Eureka Sound Formation in all hitherto studied sections of the Kanguk Formation.

Arctic seaways of late Campanian and Maestrichtian time. As pointed out by Birkelund (1965, pp. 167-168, Table 3), the presence of *Pseudophyllites skoui* closely related to *P. peregrinus* of the Indo-Pacific Province in the early and late Campanian rocks of West Greenland is difficult to explain without suggesting the existence of a direct and easy connection between the Pacific and Arctic seas at that time.

The presence of *Saghalinites wrighti*, and *Hypophylloceras (Neophylloceras) groenlandicum* in the Maestrichtian rocks of West Greenland (Birkelund, 1965, p. 168, Table 3) points in the same direction as these species are just as similar to their Indo-Pacific counterparts as is *P. skoui*.

As pointed out by Usher (1952), Matsumoto (1959a, 1959c, 1959d, 1960), Jones (1960, 1963), Birkelund (1965) and the writer (*see* pp. 26-32, Fig. 4) all Upper Cretaceous faunas of the Pacific Coast of North America are quite unlike their Western Interior counterparts. Usher (1952, p. 42) and Matsumoto (1960, p. 170) have, therefore, postulated the absence of any direct connection between these basins and the existence of a great barrier separating them. This conclusion was fully confirmed by the writer's research (pp. 26-32, Fig. 4) but the above discussed faunal affinities may be explained by the existence of a roundabout Campanian and Maestrichtian seaway extending from southeastern Alaska across Seward Peninsula and then beneath the Arctic Ocean north of Alaska toward the central part of Sverdrup Basin. At the latter point it would join the southern Ellesmere Strait leading toward the Disco Bay basin (*see* below). The existence of such a seaway would accord with the known geological facts and at the same time explain the affinities of the West Greenland and North Pacific marine faunas in the upper Campanian and Maestrichtian and the almost total dissimilarity of the contemporary North American Western Interior and North Pacific marine faunas.

The apparent lack of North Pacific elements in the older ammonite faunas of West Greenland (Birkelund, 1965, pp. 166-167, Table 3) suggests that the above discussed seaway opened up in the latest lower Campanian.

It is generally assumed that the present outcrop areas of the upper Campanian and Maestrichtian marine rocks (middle and upper Lea Park, Bearpaw, Riding Mountain, Pembina) in the Canadian Western Interior Region are more or less representative of the actual areal extent of the seas concerned (e.g. L.S. Russell, 1939, pp. 90, 92-93, Figs. 2-6; Williams and Burk, Jr., 1964, p. 188, Figs. 12-18 to 12-21 inclusive; Caldwell, 1968, p. 1, Figs. 2, 3; Warren and Stelck, unpublished manuscript; Ziegler, 1969, p. 24). Already the absence of any shoreward facies changes at or near the northern erosional edges of above mentioned formations (e.g. Wickenden, 1945) militates against this hypothesis which is, furthermore, incompatible with the paleobiotic evidence now available.

As pointed out by Jeletzky (1950, p. 23) on the basis of scant and partly erroneous literature data, the late Campanian and Maestrichtian faunas of the Canadian Western Interior Region have important faunal affinities with their West Greenland and west Siberian counterparts. According to Birkelund (1965, pp. 166-168, Table 3) all hitherto known late Campanian and Maestrichtian ammonite faunas of West Greenland are intimately allied to their North American counterparts on the specific level. Most of the species concerned are the Boreal forms which are native to the midcontinental basin of North America but very rare or absent in the contemporary Tethyan seas of the Gulf of Mexico. Some identical or closely related species such as *Scaphites (Discoscaphites)* ex gr. *waagi-mandanensis-cheyennensis* and *Baculites* cf. *meeki*, are only known in West Greenland and in the midcontinental basin of North America (Birkelund, 1965, pp. 122-124, 128-129, 167-168, Table 3; Waage, 1968, p. 145). The Maestrichtian inoceramids of the two regions (*Tenuipteria* aff. *fibrosa* and *T. fibrosa*) are equally closely allied.

These extraordinarily close faunal affinities indicate that the previously discussed late Turonian to early Campanian marine seaway connecting the Canadian Western Interior Basin with that of West Greenland persisted through the late Campanian and well into Maestrichtian time. It is obvious that this direct connection lasted at least into late lower or? early upper Maestrichtian Fox Hills time, as affinities of the Maestrichtian ammonite faunas of West Greenland with the endemic elements of the Fox Hills ammonite faunas are especially strong (Birkelund, 1965, pp. 167-168; Waage, 1968, p. 145).

It is concluded accordingly that the late Campanian and Maestrichtian Edmonton Delta did not extend much beyond 109 degrees west at any time and that the marine deposition prevailed continuously east therefrom. It appears likely, furthermore, that the lower Athabasca River area was flooded continuously in Lea Park and Bearpaw time (Figs. 17-20). This inferred late Campanian and Maestrichtian embayment apparently limited the Edmonton Delta from the northeast. North of Athabasca area the late Campanian-Maestrichtian seaway must have been confined to the eastern side of the Mackenzie Valley. The Mackenzie Salient and the Richardson Mountains must have been well above sea level and undergoing erosion because of the nonmarine character of their sedimentation (e.g. Bonnet Plume, Monster, and Moose Channel Formations).

The recent discovery of the Maestrichtian marine rocks in Anderson River area (*see* p. 73) confirms this interpretation. There is every reason to think that the Arctic Coastal Plain section of the seaway was confined between the western side of Mackenzie Delta and Darnley Bay (Figs. 17-20).

It seems likely that between the Arctic Coastal Plain and the central part of Sverdrup Basin the late Campanian-Maestrichtian seaway discussed here was entirely beneath the Beaufort Sea. From there it extended eastwards across the northern part of the Canadian Arctic Archipelago and under Baffin Bay to the Disco Bay area (Figs. 17-20).

The alternative hypothesis of a seaway extending across Hudson Bay and northern Baffin Island, or across some part of the archipelago north of it (Rosenkrantz *et al.*, 1942) is improbable for the upper Campanian-Maestrichtian at least, because of the previously mentioned (*see* p. 70) signs of a continuous westward retreat of the southeastern shoreline of the Canadian Western Interior Basin at that time (Figs. 17-20).

GENERAL PATTERN AND PROBABLE CAUSES OF TRANSGRESSIONS AND REGRESSIONS

The previously described details of the general pattern of the Cretaceous transgressions in Western and Arctic Canada indicates that they were caused largely or? entirely by the periodic oscillatory (i.e. alternatively positive and negative) movements of major tectonic elements of the region.

As already pointed out by Jeletzky (1961b, pp. 536-543) and Jeletzky and Tipper (1968, pp. 88-89) these movements in themselves were not nearly as quasicontinuous and local as claimed by Gilluly (1965) and King (1966, pp. 11-12). However, the resulting inundations and emergences of different parts of the region are much too localized and meandering in space and time to be caused either by geologically (i.e. biochronologically) contemporary, continent or worldwide epeirogenic movements in the sense of Stille (1924, p. 363 etc.) or by eustatic oscillations of sea level in the sense of Suess (1906, pp. 538-544 etc.).

The prevalent pattern of early to mid-Lower Cretaceous transgressions appears to conform reasonably closely to Haug's (1900, p. 683; 1907, p. 505) "law of epeirogenic compensation" as most of the Berriasian to Aptian transgressions observed in the Cordilleran orogenic belt of Canada (exclusive of the eastern Cordillera) seem to occur throughout that belt and to be compensated for by the regional regressions in the nongeosynclinal (shelf in the sense of Bubnoff; *see* Jeletzky, 1963, p. 58) basins of Western and Arctic Canada. The same compensatory pattern appears to dominate the Berriasian to Aptian regressions observed in Western and Arctic Canada.

The Albian and Upper Cretaceous transgressions and regressions do not exhibit any obvious overall compensatory pattern similar to that of early to mid-Lower Cretaceous time. The post-Aptian inundations and emergences of the residual marine troughs of the Canadian Western Cordilleran belt apparently followed their own rhythm unrelated to that of the inundations and emergences occurring in the same epoch in the Canadian Western Sedimentary basins. This disappearance of an overall compensatory pattern may be related to the previously discussed permanent isolation of these two tectonic regions by land barriers erected by the interregional Aptian orogeny.

The Albian and Upper Cretaceous inundations and emergences of the Canadian Western Interior basins (as distinct from the Sverdrup Basin of the Canadian Arctic Archipelago) apparently were largely caused by the oscillatory movements of the tectonically active land belt limiting them from the west (Rocky Mountains) or northwest (Mackenzie, Wernecke and Ogilvie Mountains). So far as known, these oscillatory movements had little or(?) no effect on the central and eastern parts of these basins but this may well be simulated by the extreme scarcity of data available about their eastern margins.

The Albian and Upper Cretaceous transgressions and regressions recorded along the western and southwestern margins of the Canadian Western Interior basins often exhibit considerable localizations and irregularities in time and in space as described in the corresponding sections of the previous chapter. These localizations and irregularities appear to be controlled by the more or less uncoordinates (independent?) oscillations of the individual tectonic elements of the adjoining tectonic land, notably the Aklavik Arch, the tectonically positive western part of the Mackenzie Salient (apparently an ancient northeast-trending arch), Sweetgrass Arch, and related positive tectonic elements situated south of the International Boundary (Williams and Burk, Jr., 1964, p. 186).

The data available are insufficient to attempt any generalizations about the overall pattern of Albian and Upper Cretaceous transgressions and regressions in Sverdrup Basin and adjacent parts of the Canadian Arctic Archipelago and its relationship with that of the contemporary Canadian Western Interior basins.

GENERAL CAUSES OF FAUNAL DIFFERENTIATION

The existence of paleobiotically recognizable, worldwide climatic belts in the Cretaceous is well documented by work of many geologists and paleontologists (e.g. Uhlig, 1911; Diener, 1925; Taylor, 1940; Shatsky, 1954; Schwarzbach, 1961, p. 139; Shulgina, 1966; Saks and Nalniaeva, 1966). These belts included the tropical to subtropical belt of the low latitudes (Tethyan or Mesogean Realm) and two extremely wide warm-temperate belts (the so-called Boreal and Antiboreal or Antarctic realms) comprising the rest of the Earth's surface to the north and to the south of the tropical to subtropical belt.

The previously discussed Cretaceous biotic provinces of Western and Arctic Canada conform essentially to the worldwide pattern of sublatitudinally oriented, obviously temperature-controlled Tethyan and Boreal biotic realms. The existence of a north-south directed and northward sloping temperature gradient in the North Pacific and North American Boreal provinces of Western and Arctic Canada is evidenced by the previously discussed (pp. 10-16, Fig. 4) gradual northward depauperation or disappearance of all Tethyan faunal elements within these provinces and in adjacent regions of North and Central America. Conversely, all characteristic Boreal faunal elements become progressively scarcer or disappear altogether toward the south in these two provinces. These regular north-south oriented faunal changes parallel exactly those observed by many workers (e.g. Jeletzky, 1948, 1958a; Naidin, 1954; Shulgina, 1966; Saks and Nalniaeva, 1966) in the Cretaceous basins of northern Eurasia. Most of these faunal changes are accompanied by a characteristic intermingling of the Tethyan and Boreal faunal elements near sublatitudinally-oriented boundaries of these realms. This attests to the availability of easily accessible seaways connecting the Tethyan and Boreal basins concerned and rules out effectively the decisive (as distinct from complicating; *see* below) influence of salinity and physical barriers upon these interprovincial faunal changes.

The Cretaceous north-south oriented temperature gradients were much less steeply sloping northward than those existing today. This is indicated by an almost complete absence of the sharp faunal break that occurs between the Recent subtropical and temperate faunas in the Cretaceous marine faunas of Western and Arctic Canada and adjacent regions of North and Central America. The boundaries between the North Pacific and North American Boreal provinces in northwestern Canada and between the North American Boreal and the Gulf Tethyan provinces in the southern United States are characterized by changes in the relative abundance rather than by a complete mutual exclusion of the faunal elements characteristic of the respective provinces, except under the special circumstances discussed below.

The approximately sublatitudinal distribution of most Cretaceous marine invertebrates (e.g. ammonites, nonrudistid pelecypods, brachiopods, gastropods, various echinoderms, etc.) is complicated by a great many local to regional irregularities evidently attributable to factors other than the northward sloping temperature gradient.

The previously discussed deep but local and temporary penetration of the Berriasian to Barremian cylindroteuthidid belemnites, polyptychitid, simbirskitid, and craspeditid ammonites, and Buchias deep into the Canadian and American (as far south as northwestern California; *see* Jeletzky, 1965a; Anderson, 1938) part of the North Pacific Province appears, for example, to be related to the existence of the Neocomian (i.e. from the Berriasian to late Barremian) Dawson City Strait. The southward migration of these characteristically Boreal fossil groups through this strait may have been facilitated by temporary drops of temperature in the Berriasian and Hauterivian times. These temperature fluctuations were, however, probably a minor contributing factor only. Another possible contributing factor could be the existence of a relatively cold sea current which flowed southward through the Dawson City Strait and spread along the structural grain of the Cordilleran orogenic belt to northwestern California. This cold current could also have hindered the penetration of the more isothermal Tethyan fossil groups (e.g. echinoids, starfish, sea lilies, brachiopods) into the Neocomian North Pacific Province. The thermal influence of the Dawson City Strait was, however, not strong enough to affect decisively the flourishing of other, presumably more eurythermal, Tethyan forms (e.g. the berriasellid, ancyloceratid (sensu Wright, 1957) heteroceratid, phylloceratid, lytoceratid, and desmoceratid ammonites; Trigoniidae, naticid, nerineid, and neritid gastropods) in the North Pacific Province of Canada. It was, therefore, incapable of changing the basically Tethyan character of the Neocomian invertebrate faunas of this province determined by the overall influence of the Cretaceous climatic belts. The modifying paleobiotic role of the geographical factor in this instance is, furthermore, suggested by the previously mentioned northward migration of some of the above mentioned Tethyan ammonites through the Dawson City Strait and their temporary colonization of parts of the North American Boreal Province.

The relative scarcity to almost complete absence of Boreal faunal elements in the Aptian to Maestrichtian invertebrate faunas of the North Pacific Province of Canada is evidently caused by the previously discussed permanent closure of the Dawson City Strait at the end of the Barremian or early in the Aptian. This closure notwithstanding, the Aptian to Maestrichtian water temperatures of the North Pacific Province must have remained closely comparable to those of its Neocomian precursor and below those of southern California, northern Mexico and Texas. This is indicated by the fact that the closure of the Dawson City Strait did not result in the mass immigration of any of the most stenothermal and warmloving Tethyan fossil groups (e.g. colonial corals, rudistids, orbitoids) previously absent in the North Pacific Province of Canada.

The previously mentioned sudden appearance of a few typical Tethyan ammonites in the otherwise typically Boreal latest lower Campanian, upper Campanian and Maestrichtian faunas of West Greenland in the very heart of the North American Boreal Province provides another striking example of the complicating influence of factors other than the northward sloping of the temperature gradient. This deep but local and temporary invasion evidently followed the opening of a seaway across western Alaska and beneath the present Beaufort Sea in the late lower Campanian. The rest of the marine invertebrate fauna suggests that the temperature of the late lower Campanian to Maestrichtian seas of West Greenland remained closely comparable to those of their late Turonian to earlier lower Campanian precursor which were devoid of the Tethyan faunal elements.

The strong diversification of the Boreal Cenomanian to Maestrichtian invertebrate faunas of the North American Boreal Province following the opening of a wide marine connection with the Tethyan seas of the Gulf region in the late middle Albian is yet another example of the modifying local influence of geographical factors upon the climatically controlled sublatitudinal distribution of the Tethyan and Boreal marine biotas of the Cretaceous. This opening of the midcontinental seaway connecting the Boreal seas of the Canadian Arctic and West Greenland with the Tethyan seas of the Gulf region resulted, furthermore, in the longitudinal ranges of many inhabitants of the North American Boreal Province in excess of 3,500 miles (e.g. from the Canadian Arctic Archipelago or West Greenland to Texas or northern Mexico). These extraordinarily wide longitudinal ranges of genera and sometimes species or invertebrates (e.g. *Discoscaphites*, *Scaphites*, *Clioscaphites*, *Haresiceras*, *Actinocamax*, *Belemnitella*, *Sphenoceramus*) are closely matched by those of the contemporary marine vertebrates (D.A. Russell, 1967, p. 36).

Only a few most characteristically Tethyan fossil groups, such as colonial corals, rudistids, and orbitoid foraminifers, do not exhibit the above mentioned striking but local and temporary irregularities of geographical distribution. Unlike other above mentioned marine invertebrates, these fossil groups were essentially restricted to the Central American Tethyan basins south of the North Pacific and North American Boreal provinces throughout the Cretaceous.

In spite of the availability of easily accessible connecting seaways during the most part of the Cretaceous, these fossil groups penetrated only more or less occasionally into those parts of the North Pacific and North American Boreal provinces situated between Texas and southern California on the one hand and the Canadian border on the other. The colonial corals, rudistids, and orbitoids are unknown in the Canadian parts of these two provinces, except for the unique occurrence of a rudistid fragment in the Bearpaw Formation of southwestern Saskatchewan (Caldwell, 1968, p. 74).

The above discussed common but temporary and geographically restricted penetration of most Cretaceous marine invertebrates far beyond their normal Boreal and Tethyan habitats in North America is best explained by assuming that the Cretaceous north-south oriented temperature gradients were too shallowly inclined northward to control rigorously their geographical distribution. Only the most warmloving and stenothermal invertebrate groups, such as colonial corals, rudistids, and orbitoid foraminifers, were exceptions to this rule. The quite obvious overall influence of the Cretaceous temperature gradients on the other more eurythermal marine invertebrates must have been feeble enough to be commonly strongly modified or even completely offset by the appearance or disappearance of land and deep sea barriers, warm or cold currents, and other local or regional factors acting singly or in various combinations.

The salinity and facies have been believed to be the primary causes of faunal provincialism in the Jurassic by Nikitin (1886), Ortmann (1896) and recently by Hallam (1969). Regardless of the actual role of these factors in the origin of the Jurassic Tethyan and Boreal Realms, they hardly influenced to any extent the provincial (as distinct from local or regional) distribution of marine Cretaceous faunas of North America. Firstly, the previously mentioned northward depauperation and disappearance of colonial corals, rudistids, and orbitoid foraminifers proceeded essentially independently of facies patterns. This depauperation and disappearance occurs at comparable rates in the predominately carbonate facies of the Upper Cretaceous midcontinental basin (e.g. between Texas and eastern Manitoba), in the shelf clastics of the same basin (i.e. between New Mexico and southern Saskatchewan), and in the predominantly volcanic clastics of the contemporary basins of the Cordilleran orogenic belt (i.e. between southern California and western British Columbia). Secondly, the same appears to be true of the northward depauperation and disappearance of the Upper Cretaceous Tethyan ammonites in the midcontinental Boreal basin of North America which occurs at similar rates in the carbonate and clastic facies of this basin.

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