LOWER BAJOCIAN (JURASSIC) AMMONOID FAUNAS,

WESTERN AMERICAS

LOWER BAJOCIAN (JURASSIC) AMMONOID FAUNAS OF THE WESTERN AMERICAS

By

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ABSTRACT

The Lower Bajocian (Jurassic) ammonoid faunas from the lower parts of the Yakoun Formation along Skidegate Inlet (Queen Charlotte Islands) belong to three distinct faunules, probably of different ages: the *Zemistephanus richardsoni* faunule at MacKenzie Bay (upper Sauzei Zone or lowermost Humphriesianum Zone), the *Stephanoceras skidegatense* - *Chondroceras defontii* faunule at Richardson Bay (Humphriesianum Zone) and the *Stephanoceras itinsae* - *Chondroceras oblatum* faunule on South Balch Island (upper Humphriesianum Zone).

Taxonomic and stratigraphic comparisons with other ammonoid faunas from the western margins of both North and South America show that close affinities exist with southern Alaska, mainland British Columbia, western Alberta and eastern Oregon, and lesser ones with western interior United States, Chile and Argentina. Larger samples led to a number of taxonomic revisions by establishing the range of variation of species.

The following dimorphic species are recognised: *Stephanoceras itinsae* (McLearn) ♀ & ♂ [= *Stephanoceras yakounense* McLearn ♀ - *Itinsaites itinsae* McLearn ♂], *Stephanoceras skidegatense* (Whiteaves) ♀ & ♂ [microconch new], *Zemistephanus richardsoni* (Whiteaves) ♀ & ♂ [microconch new], *Chondroceras oblatum* (Whiteaves) ♀ & ♂ [microconch new] and *Chondroceras defontii* (McLearn) ♀ & ♂ [microconch new]. As a consequence of these dimorphic pairings the microconch genus *Itinsaites* McLearn, 1927 is regarded as a junior subjective synonym of *Stephanoceras* Waagen, 1869, and *Kanastephanus* McLearn, 1927 as a subjective synonym of *Zemistephanus* McLearn, 1927. The new species *Zemistephanus alaskensis* ♀ is described.

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?Eutrephoceras sp. indet.
Cenoceras sp. indet.

CHAPTER 1

INTRODUCTION

Early failures to separate Jurassic and Cretaceous faunas from the Queen Charlotte Islands derived from the mixing of collections thought to have come from the same strata exposed on several islands in Skidegate Inlet (Whiteaves, 1876, p. 6). MacKenzie (1916) finally recognised that this confusion had arisen because of failure to separate sandstones of the Cretaceous Haida Formation from the underlying Middle Jurassic Yakoun Formation.

The presence of two distinct ammonite faunas within the Yakoun Formation was shown by McLearn's careful collecting from several measured stratigraphic sections (McLearn, 1927, 1949). Ammonites from three localities within the lower volcaniclastic parts of the Yakoun Formation (Richardson Bay, MacKenzie Bay and South Balch Island; see Text-fig. 1) were presumed to represent a single ammonite faunule belonging to the Humphriesianum Zone (McLearn, 1949; Imlay, 1964, p. B19). Arkell (1956, p. 542), however, suggested that the fauna from MacKenzie Bay was older and possibly represented the Sauzei Zone; this was based on misidentification of *Zemistephanus carlottensis* (Whiteaves) ♀ with *Pseudotoites* (p. 81).

Published faunal lists and descriptions of Lower Bajocian stephanoceratid ammonites from localities in western Canada and Alaska also indicated the presence of forms now believed to be sexual dimorphs.

I made new collections from the Queen Charlotte Islands and parts of western Alberta during the summer of 1971 with a view to:

1. clarifying the faunal associations at each of the three localities in the lower parts of the Yakoun Formation where the supposed "Lower Yakoun or *Stephanoceras* fauna" was present;
2. determining the stratigraphic sequence and ages of these ammonite faunas and attempting to correlate them with similar faunas from Alaska, mainland western Canada and United States, Chile and Argentina;
3. obtaining sufficient material for biometric analysis in an attempt to demonstrate infraspecific morphological identity of the juvenile stages of several sexual dimorphs and allow pairing at the species level.

CHAPTER 2

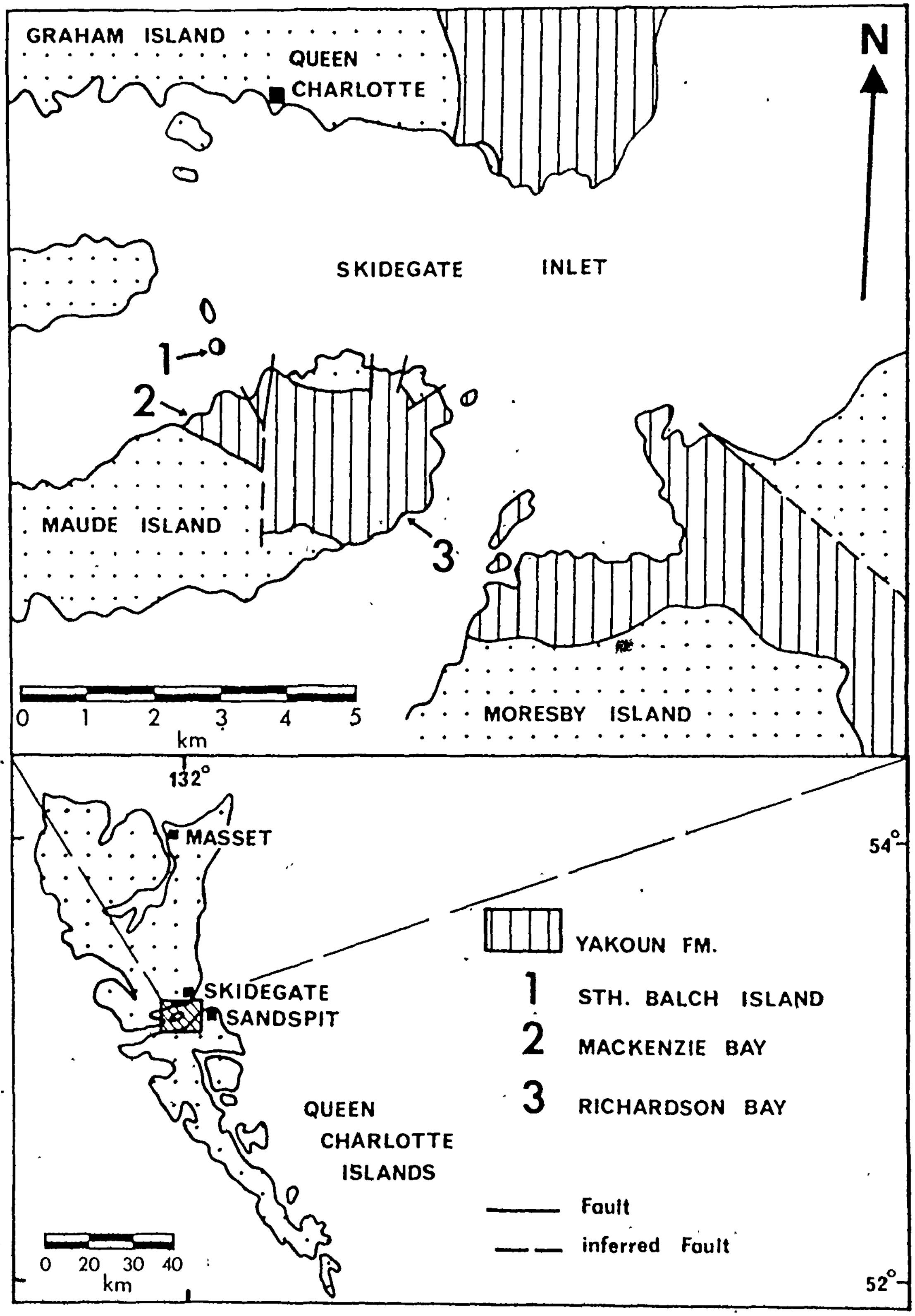
FIELDWORK AND FOSSIL MATERIAL

2.1 Fieldwork

Strata of the lower Yakoun Formation crop out along the shores of Skidegate Inlet, Queen Charlotte Islands and on several small islands in the Inlet (Text-fig. 1). Ammonites of Lower Bajocian age (here defined to include "Sowerbyi" - Humphriesianum Zones) have previously been recorded and described by a number of writers (Chapter 4.1.1a) from three localities: Richardson Bay and MacKenzie Bay on the south-east and north-west shores respectively of Maude Island and on South Balch Island. These localities are easily accessible by small boat from Queen Charlotte City on the north shore of Skidegate Inlet. New collections were made by me in May-June, 1971 from these three localities. Detailed measurements of each section, with *in situ* collecting of fossils, was undertaken in an attempt to establish the stratigraphic and geographic distributions of ammonites. Special attention was given to those forms believed to represent dimorphic pairs.

Stratigraphic measurement, correlation and fossil collecting was hampered by several physical features of these islands:

1. The average tidal range of approximately 7.5 m allows access to much of the rock platforms along the shore only during short periods each



Text-fig. 1. Locality map showing three main localities in Skidegate Inlet from which ammonite faunas from the lower parts of the Yakoun Formation are described.

day. Much of the exposed platform is covered by seaweeds and other marine life which makes collecting more difficult. Many of the fossils, covered by water much of the time, are badly weathered and difficult to remove or transport in a useful state.

2. Although exposure on the wide, wave-cut platforms is good, sections are often interrupted by Recent beach deposits, ranging from sand and pebbles to large boulders. Thick forests of pine, cedar and hemlcok with a thick undercover of mosses, ferns and fallen trees cover the islands to within a few metres of the high tide level, so that tracing beds across even the smallest islands is not possible. Streams which would expose rock outcrops occur only on the largest islands.
3. Many small faults break up the sections but, again, cannot be traced laterally for any distance.

Access to isolated outcrops of the Yakoun Formation in the interior of the two largest islands (Graham and Moresby) is by private forestry roads. Outcrops yielding a few specimens of Lower Bajocian age are not easily located and they are of no biostratigraphic value for the lower part of the Yakoun Formation.

Collections were also made from the Rock Creek Member of the Fernie Group in Ribbon Creek, southern Alberta. This outcrop is well exposed and easily accessible from the Kananaskis-Coleman road.

Attemps during the 1971 field season to make collections from a number of localities within Jasper National Park from which Lower Bajocian ammonites have previously been recorded were blocked by bushfires and the subsequent closing of all access roads within the Park.

2.2 Other Material

Collections made by me from the Queen Charlotte Islands were supplemented with material collected by A. Sutherland Brown between 1958 and 1965 and some undescribed specimens collected by F. H. McLearn; this material was made available on loan from the collections of the Geological Survey of Canada in Ottawa. Two specimens of *Stephanoceras itinsae* (McLearn) ♀ known to have come from Skidegate Inlet (the lithology of the matrix is identical with that on specimens collected by me from South Balch Island) were loaned by the Geology Department museum at the University of British Columbia. Comparative material from southern Alaska was obtained on loan from the U.S. National Museum in Washington, D.C. Material collected by G. E. G. Westermann and myself from the Ribbon Creek locality was also included in this study. Specimens from the Rock Creek Member collected from several scattered localities in northern Alberta and kept in the collections of the Geology Department, University of Alberta, were examined, but most lacked information on locality, associated fauna and precise stratigraphy.

Holotypes and other figured specimens of species based on material from the Queen Charlotte Islands, western Alberta and southern Alaska were re-examined; when such material was not easily accessible plaster molds were obtained.

Comparison of North American with North-west European species was facilitated by visits to the British Museum (Natural History) and British Geological Survey Museum in London and the Sedgwick Museum in Cambridge in 1972.

2.3 Repositories

Institutions in which material described or figured in this thesis is kept are indicated by the following prefixes:

McM -- Department of Geology paleontology collections, McMaster University, Hamilton, Ontario; includes all material collected from the Queen Charlotte Islands and southern Alberta by me, as well as material from Ribbon Creek collected by G. E. G. Westermann.

GSC -- Geological Survey of Canada collections, Ottawa; includes material collected by Richardson, McLearn, Sutherland Brown and Frebold.

UBC -- University of British Columbia, Geology Department museum.

USNM -- U. S. National Museum, Washington, D. C.; from southern Alaska. Unfigured material from southern Alaska is identified by the U. S. Geological Survey Mesozoic locality numbers with decimal digits added by me for identification of individual specimens from each locality.

UA -- University of Alberta, Edmonton; Geology Department.

CHAPTER 3

METHODS OF STUDY

3.1 Measurements

Whenever possible, measurements were made using polished cross-sections or broken whorls obtained during dissection of specimens. Cross-sections were drawn from the same material either directly using a camera lucida or by tracing photographs. For specimens on loan which could not be cut or broken, cross-sections were obtained using a Formagage.

The earliest phragmocone whorls were obtained by dissection of suitably preserved material under a binocular microscope using dissecting needles. Protoconchs thus obtained were then drawn with the aid of a camera lucida. Suture lines were exposed after removal of the test by mechanical flaking and careful etching with dilute (10%) HCl; they were drawn using the camera lucida and the microscope stage apparatus described by Palframan (1968).

3.2 Terminology

For most features of the ammonoid shell the terminology in the Treatise on Invertebrate Paleontology, volume L (Arkell, 1957, pp. L81-100) has been used. The genera discussed in this thesis have poorly defined umbilical walls, lacking any "shoulder" or "edge" differentiating the umbilical wall from the flank. Hence the term "flank" is used for that part of the whorl extending from the umbilical seam to the lateral shoulder (though even this is hard to define in *Chondroceras* and some mature whorls of Stephanoceratidae).

3.3 Statistics

Measurements used in the statistical calculations and plotted on the various graphs in this thesis are given in Appendix 1.

As outlined in Chapter 8.1 the plots of whorl dimensions (D vs. W, H and U) are "mass curves" with usually more than one measurement from each specimen. The regression lines illustrated on these graphs were calculated using only data from the phragmocone whorls (excluding measurements from both the first whorl and body chamber), this being the stage during which growth is isometric.

Appendix 2 lists the data and results of formal statistical comparisons of the growth patterns of macroconch-microconch pairs. Here only a single measurement from each specimen was used; these measurements were selected to cover the range of growth stages between the end of the first whorl and the maximum septate diameter attained by the smaller microconchs. This represents the range over which dimorphic pairs are expected to follow the same growth patterns. The similarity of these growth patterns was tested using the statistical methods outlined by Brownlee (1960, pp. 334-357). Tests of significance are all at the 95% level of confidence.

CHAPTER 4

STRATIGRAPHY AND FAUNAS

4.1 FOSSIL ZONATION

Table 1 shows the scheme of Zones and Subzones used here for the Bajocian Stage. Those Zones previously making up the Lower Bajocian (Opalinum to Concavum) now comprise the Aalenian Stage (Colloque du Jurassique a Luxembourg, 1967); the remaining Zones are divided into Lower Bajocian (Discites to Humphriesianum) and Upper Bajocian (Subfurcatum to Parkinsoni). This usage follows the revised Zonal schemes

	STAGE		ZONE
Middle Jurassic	Callovian		
	Bathonian		
	Bajocian	Upper	Parkinsoni
			Garantiana
			Subfurcatum
		Lower	Humphriesianum
			Sauzei
			Laeviuscula
			Ovalis
			Discites
	Aalenian		

Table 1. Stages and Zones for the Middle Jurassic.

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Table 2. Correlation of some Lower Bajocian ammonite faunas from Europe and the western Americas.

									1964; Westermann 1967)	
SUBFURCATUM		Garantiana ?baculata		Leptosphinctes aff. davidsoni Stephanoceras sp. Teloceras banksi Teloceras cf. blagdeni Cadomites deslongchampsi C. cf humphriesiformis Strenoceras cf. subfurcatum Orthogarantiana sp. Chondroceras tenue Caumontisphinctes aplous C. diniensis Infraparkinsonia phaulus		Caumontisphinctes aplous Cleistosphinctes cleistus Vermisphinctes cf. subdivisus Oppelia subradiata Strigoceras truellii			Megasphaeroceras rotundum Normannites vigorosus Leptosphinctes delicatus L. cliffensis Sphaeroceras talkeetnanum Liroxyites kellumi Spiroceras ? Lissoceras bakeri	
HUMPHRIESIANUM	BLAGDENI	Teloceras blagdeni	BLAGDENI	Teloceras blagdeni T. banksi	BLAGDENI	Teloceras subblagdeni T. blagdeni T. banksi T. acuticostatum Itinsaites mackenzii Normannites orbignyi N. quenstedti Stemmatoceras frechi Stephanoceras humphriesianum S. mutabile	BLAGDENI	Teloceras coronatum T. blagdeni T. banksi Teloceras subblagdeni T. cf triptolemus T. aff. chapuisi T. aff. acuticostatum T. aff. schleichershofense Stemmatoceras subcoronatum S aff. krumbecki Cadomites septicostatus Normannites orbignyi N crassicostatus Itinsaites mackenzii	2of	
	HUMPHRIESIANUM	Stephanoceras mutabile S pyritosum S. aff. triplex Normannites ?orbignyi N ?densum	HUMPHRIESIANUM	Dorsetensia complanata D pulchra D regrediens D subtecta Chondroceras delphinus C. evolvescens C. gervillii Sphaeroceras brongniarti Stegoxyites parcicarinatus Oppelia subradiata Poecilomorphus cycloides Strigoceras bessinum Stephanoceras mutabile S zieteni S. crassicostatum S. gibbosum Normannites orbignyi N. formosus Teloceras blagdeniforme T. acuticostatum	STEPHANOCERAS	Stephanoceras mutabile Stemmatoceras cf. triplex Skirroceras cf. thorali Normannites circularis N. turgidus	HUMPHRIESIANUM	Oecotraustes aff. umbilicatus Germanites aff. bicostatus Normannites aequus Itinsaites aff. variecostatus I gracilis Stephanoceras umbilicus S. mutabile S. basileense S mutabiliforme S weisserti S. aff vindobonense Stemmatoceras aff. subcoronatum Cadomites stephanoceratiformis C. feuracorus C. aff. perplicatus Teloceras aff. chapuisi T. gibbosum Stephanoceras plagium S. pseudohumphriesi S. sorentheuthense Teloceras sp Chondroceras gervillii C. wrighti C. russelli Schmidtoceras orbignyanum Oecotraustes umbilicata Poecilomorphus cf. cycloides P. cf. regulatus Normannites Germanites Itinsaites Dorsetensia Sonninia furticarinata S. diueliformis Stephanoceras humphriesianum S. freycineti S. nodosum Skirroceras macrum		
	CYCLOIDES	Oppelia ?subradiata Stephanoceras mutabile S. nodosum Normannites ?orbignyi N. ?densum Chondroceras evolvescens Dorsetensia liostraca D. romani Sonninia aff. furticarinata Poecilomorphus cycloides			POECILOMORPHUS	Skirroceras macrum Schmidtoceras schmidti Chondroceras orbignyanum C. gervillii C evolvescens Stemmatoceras frechi S subcoronatum Stephanoceras humphriesianum S. zieteni Itinsaites latansatus Normannites quenstedti Dorsetensia romani D. liostraca D. complanata Poecilomorphus cycloides P. umbilicatus Sonninia alsatica S. patella S. propinquans Oppelia subradiata Epalxites cf. anceps			Zemistephanus carlottensis Normannites crickmayi Chondroceras oblatum C. allani C. defontii	Ste Ski Cho Ste Ste Cho
SAUZEI	HEBRIDICA	Stephanoceras nodosum S. aff macrum ?Chondroceras evolvescens Lissoceras oolithicum Dorsetensia pinguis D. hannoverana D. hebridica Sonninia aff. furticarinata		Emileia bulligera E. pseudocontrahens E. polymera Otoites fortis O. sauzei O. cf. delicatus Kumatostephanus kumaterus K. turgidulum K. triplicatum Labyrinthoceras mentacum Sphaeroceras manselli Skirroceras kalus S. bayleanum Sonninia felix S. propinquans S. corrugata Witchellia? hebridica Pelekodites sulcata Bradfordia Lissoceras semicostulatum Strigoceras strigifer Toxamblyites aff. arcifer ?Normannites aff. kialagvikensis ?N. aff. sauzeiformis		Sonninia alsatica Otoites contractus Sonninia mesacantha S. patella ?Pelekodites pinguis ?P sulcata Sonninia propinquans Witchellia laeviuscula Strigoceras cf. strigifer Labyrinthoceras perexpansum Emileia polyschides E. cf. brocchi Otoites contractus Skirroceras nodosum Germanites rugosus G. aequicostatus Normannites spp.		Otoites sauzei O. pauper Emileia brocchi E. polymera E. polyschides Sonninia patella S. propinquans S. felix Skirroceras leptogyrale S. rhytus S. bayleanum S. dolichoecus S. skolex S. kalus Kumatostephanus perjucundum K. kumaterum K. turgidulum	Zemistephanus richardsoni Z. carlottensis Z. alaskensis Normannites cf crickmayi Chondroceras allani C cf. defontii Sonninia tuxedniensis Stemmatoceras cf. palliseri Skirroceras kirschneri Emileia constricta Sonninia tuxedniensis Lissoceras cf. semicostulatum Strigoceras cf. languidum Stephanoceras cf nodosum Stemmatoceras cf. triptolemus [illegible] crassicostatus Normannites kialagvikensis Otoites ?filicostatus O. cf. contractus Emileia constricta Papilliceras cf arenata Sonninia tuxedniensis Witchellia adnata W ? eguilonia Arkelliceras Bradfordia costidensa Lytoceras Holcophylloceras costisparsum Kacrophylloceras Phylloceras cf. kunthi	Zemi Z. c Z. a Chon
	SAUZEI	Sonninia cf. sowerbyi S. cf. propinquans S. corrugata Papilliceras arenata P. mesacantha Pelekodites macer Strigoceras bessinum Emileia								
LAEVIUSCULA		Witchellia aff. rubra W. aff. laeviuscula W. aff. romanoides Pelekodites zurcheri P. macer P. minimus Sonninia corrugata Otoites		Emileia brocchi E. bulligera E. polyschides E. catamorpha E. crater E. contrahens Otoites contractus O. cf. delicatus Frogdenites spiniger F. cf. profectus Chondroceras Mollistephanus aff. mollis Skirroceras aff. kalus S leptogyrale Bradfordia cf. inclusa B. liomphala B cf. inclusum		Sonninia sowerbyi Fontannesia grammoceroides Emileia cf. contrahens Frogdenites pro' ctus F. spiniger Witchellia laeviuscula Sonninia propinquans ?Pelekodites pinguis Bradfordia sp.		Otoites contractus Skirroceras Witchellia Witchellia laeviuscula Sonninia jugifera S gingensis S gelasina Papilliceras polyacantha P. arenata Bradfordia praeradiata Trilobiticeras Normannites Emileia		

3b

Hillebrandt 1970)

	Megasphaeroceras rotundum Normannites vigorosus Leptosphinctes delicatus L. cliffensis Sphaeroceras talkeetnanum Liroxyites kellumi Spiroceras ? Lissoceras bakeri			Spiroceras bifurcatum S. annulatum Sphaeroceras cf. brogniarti Normannites aff. orbignyi Stephanoceras Leptosphinctes cf. evolutus L. cf. leptus Lupherites senecaensis Prorsisphinctes	Teloceras cf. multinodum Itinsaites ? Cadomites cf. cosmopolitum leptosphinctids ? parkinsoniids ?	Teloceras multinodum Cadomites dunkeri Normannites (?) vigorosus N. cf. itinsae Spiroceras bifurcatum Megasphaeroceras cf. rotundum Eocephalites sp.
						Cadomites cf. psilacanthus Teloceras cf. coronatum T. cf. multinodum Stephanoceras cf. triplex
us us natum rmis tes tum	Zemistephanus carlottensis Normannites crickmayi Chondroceras oblatum C. allani C. defontii	Stephanoceras itinsae Skirroceras casmanoi Chondroceras oblatum Stephanoceras skidegatense Stephanoceras sp. Chondroceras defontii	Teloceras dowlingi T. crickmayi Chondroceras oblatum C. allani Stephanoceras itinsae		Stephanoceras Chondroceras	Dorsetensia aff. deltafalcata D. liostraca D. romani D. cf. complanata D. tecta Stephanoceras cf. humphriesianum S. nodosum Epalxites anceps Chondroceras submicrostomum Chondroceras sp. Chondroceras submicrostomum
	Zemistephanus richardsoni Z. carlottensis Z. alaskensis Normannites cf. crickmayi Chondroceras allani C. cf. defontii Sonninia tuxedniensis Stemmatoceras cf. palliseri Skirroceras kirschneri Emileia constricta Sonninia tuxedniensis Lissoceras cf. semicostulatum Strigoceras cf. languidum Stephanoceras cf. nodosum Stemmatoceras cf. triptolemus Parabigotites crassicostatus Normannites kialagvikensis Otoites ?filicostatus O. cf. contractus Emileia constricta Papilliceras cf. arenata Sonninia tuxedniensis Witchellia adnata W.? aquilonia Arkelloceras Bradfordia costidensa Lytoceras Holcophylloceras costisparsum Macrophylloceras Phylloceras cf. kunthi	Zemistephanus richardsoni Z. carlottensis Z. alaskensis Chondroceras sp.	Arkelloceras aff. mclearni Stemmatoceras aff. frechi Kumatostephanus cf. turgidulum	Dorsetensia oregonensis Pelekodites dobsonensis Poecilomorphus cf. varius Chondroceras allani Sphaeroceras sp. Normannites orbignyi N. crickmayi Stephanoceras aff. nodosum Skirroceras kirschneri Dorsetensia oregonensis Sphaeroceras Skirroceras kirschneri Stephanoceras Dorsetensia subtexta D. cf. edouardiana D. oregonensis Pelekodites silviesensis Skirroceras kirschneri Stephanoceras Asthenoceras delicatum Papilliceras stantoni Witchellia connata Dorsetensia pulchra D. cf. subtexta D. edouardiana D. oregonensis Pelekodites silviesensis Emileia buddenhageni Otoites contractus Normannites cf. densus N. crickmayi Stephanoceras mowichense Skirroceras juhlei Phaulostephanus oregonense Parabigotites crassicostatum	Dorsetensia aff. edouardiana D. blancoensis D. mendozai Sonninia alsatica Papilliceras espinazitensis Otoites cf. gottschei Emileia multiformis E. contracta E. aff. polyschides Chondroceras cf. giebeli C. ex. gr. defontii C. cf. allani Sonninia? ovalis S. alsatica Skirroceras cf. macrum Dorsetensia aff. edouardiana D. mendozai D. blancoensis Pseudotoites cf. transatlanticus Witchellia Euhoploceras Stephanoceras ex. gr. nodosum Bradfordia Fissilobiceras cf. zitteli	Emileia multiformis E. multifida Otoites contractus Chondroceras aff defontii Poecilomorphus subdeltafalcata Papilliceras espinazitensis
				Asthenoceras delicatum Papilliceras stantoni Witchellia connata Dorsetensia subtexta D. cf. complanata Pelekodites silviesensis Emileia Stephanoceras	Pseudotoites transatlanticus P. cf. sphaeroceroides P. cf. singularis Latotoites cf. evolutum Papilliceras espinazitensis P. cf peruana Euhoploceras amosi Puchenquia malarguensis Fissilobiceras zitteli Sonninia mirabilis S. zitteli Bradfordia cf. costidensa B. cf. helense	Sonninia altecostata Pseudotoites sphaeroceroides Sonninia adicra Pseudotoites singularis Latotoites evolutus Sonninia cf. crassispinata S. cf. ovalis

HUMPHRIESIANUM		HUMPHRIESIANUM	Stephanoceras mutabile S. pyritosum S. aff. triplex Normannites ?orbignyi N. ?densum	HUMPHRIESIANUM	Dorsetensia complanata D. pulchra D. regrediens D. subtecta Chondroceras delphinus C. evolvescens C. gervillii Sphaeroceras brongniarti Stegoxyites parcicarinatus Oppelia subradiata Poecilomorphus cycloides Strigoceras bessinum Stephanoceras mutabile S. zieteni S. crassicostatum S. gibbosum Normannites orbignyi N. formosus Teloceras ?blagdeniformis T. acuticostatum	STEPHANOCERAS	Stephanoceras mutabile Stemmatoceras cf. triplex Skirroceras cf. thorali Normannites circularis N. turgidus	HUMPHRIESIANUM	Oecotraustes aff. umbilicatus Germanites aff. bicostatus Normannites aequus Itinsaites aff. variecostatus I. gracilis Stephanoceras umbilicus S. mutabile S. basileuse S. mutabiliforme S. weiserti S. aff. vindobonense Stemmatoceras aff. subcoronatum Cadomites stephanoceratiformis C. rauracoris C. aff. perplicatus Teloceras aff. chapuisi T. gibbosum Stephanoceras plagium S. pseudohumphriesi S. togenreuthense Teloceras sp. Chondroceras gervillii C. wrighti C. russelli Schmidtoceras orbignyanum Oecotraustes umbilicata Poecilomorphus cf. cycloides P. cf. regulatus Normannites Germanites Itinsaites Dorsetensia Sonninia furticarinata S. diaciformis Stephanoceras humphriesianum S. freycineti S. nodosum Skirroceras macrum	Zemistephanus carlottensis Normannites crickmayi Chondroceras oblatum C. allani C. defontii	Stephan Skirro Chondr Steph Steph Chond
		CYCLOIDES	Oppelia ?subradiata Stephanoceras mutabile S. nodosum Normannites ?orbignyi N. ?densum Chondroceras evolvescens Dorsetensia liostraca D. romani Sonninia aff. furticarinata Poecilomorphus cycloides			POECILOMORPHUS	Skirroceras macrum Schmidtoceras schmidti Chondroceras orbignyanum C. gervillii C. evolvescens Stemmatoceras frechi S. subcoronatum Stephanoceras humphriesianum S. zieteni Itinsaites latansatus Normannites quenstedti Dorsetensia romani D. liostraca D. complanata Poecilomorphus cycloides P. umbilicatus Sonninia alsatica S. patella S. propinquans Oppelia subradiata Epalxites cf. anceps				
SAUZEI		HEBRIDICA	Stephanoceras nodosum S. aff. macrum ?Chondroceras evolvescens Lissoceras oolithicum Dorsetensia pinguis D. hannoverana D. hebridica Sonninia aff. furticarinata		Emileia bulligera E. pseudocontrahens E. polymera Otoites fortis O. sauzei O. cf. delicatus Kumatostephanus kumaterus K. turgidulum K. triplicatum Labyrinthoceras meniscum Sphaeroceras mansellii Skirroceras kalus S. bayleanum Sonninia felix S. propinquans S. corrugata Witchellia? hebridica Pelekodites sulcata Bradfordia Lissoceras semicostulatum Strigoceras strigifer Toxamblyites aff. arcifer ?Normannites aff. kialagvikensis ?N. aff. sauzeiformis		Sonninia alsatica Otoites contractus Sonninia mesacantha S. patella ?Pelekodites pinguis ?P. sulcata Sonninia propinquans Witchellia laeviuscula Strigoceras cf. strigifer Labyrinthoceras perexpansum Emileia polyschides E. cf. brocchi Otoites contractus Skirroceras nodosum Germanites rugosus G. aequicostatus Normannites spp.		Otoites sauzei O. pauper Emileia brocchi E. polymera E. polyschides Sonninia patella S. propinquans S. felix Skirroceras leptogyrale S. rhytus S. bayleanum S. dolichoecus S. skolex S. kalus Kumatostephanus perjucundum K. kumaterum K. turgidulum	Zemistephanus richardsoni Z. carlottensis Z. alaskensis Normannites cf. crickmayi Chondroceras allani C. cf. defontii Sonninia tuxedniensis Stemmatoceras cf. palliseri Skirroceras kirschneri Emileia constricta Sonninia tuxedniensis Lissoceras cf. semicostulatum Strigoceras cf. languidum Stephanoceras cf. nodosum Stemmatoceras cf. triptolemus Parabigotites crassicostatus Normannites kialagvikensis Otoites ?filicostatus O. cf. contractus Emileia constricta Papilliceras cf. arenata Sonninia tuxedniensis Witchellia adnata W.? aquilonia Arkelloceras Bradfordia costidensa Lytoceras Holcophylloceras costisparsum Macrophylloceras Phylloceras cf. kunthi	Zemis Z. ca Z. al Chond
		SAUZEI	Sonninia cf. sowerbyi S. cf. propinquans S. corrugata Papilliceras arenata P. mesacantha Pelekodites macer Strigoceras bessinum Emileia								
"SOWERBYI"	LAEVIUSCULA		Witchellia aff. rubra W. aff. laeviuscula W. aff. romanoides Pelekodites zurcheri P. macer P. minimus Sonninia corrugata Otoites		Emileia brocchi E. bulligera E. polyschides E. catamorpha E. crater E. contrahens Otoites contractus O. cf. delicatus Frogdenites spiniger F. cf. proflectus Chondroceras Mollistephanus aff. mollis Skirroceras aff. kalus S. leptogyrale Bradfordia cf. inclusa B. liomphala B. cf. inclusum Protoecotraustes spiniger Papilliceras arenata Shirbuirnia superba S. cf. trigonata S. stephani Witchellia falcata W. glauca W. actinophora W. patefactor W. plenus W. gelasinus W. sutneri W. cf. parvientarius W. connata W. albidus W. ruber W. nodatipinguis W. romanoides Pelekodites aurifer P. macer Emileites liebi Trilobiticeras Euhoploceras acantherum Sonninia gingensis S. ovalis Strigoceras compressum		Sonninia sowerbyi Fontannesia grammoceroides Emileia cf. contrahens Frogdenites proflectus F. spiniger Witchellia laeviuscula Sonninia propinquans ?Pelekodites pinguis Bradfordia sp.		Otoites contractus Skirroceras Witchellia Witchellia laeviuscula Sonninia jugifera S. gingensis S. gelasina Papilliceras polycantha P. arenata Bradfordia praeradiata Trilobiticeras Normannites Emileia		
	OVALIS		Fissilobiceras fissilobatum Euhoploceras ?cf. adicrum Shirbuirnia trigonalis						Shirbuirnia Sonninia ovalis S. rudis S. adicra Hyperlioceras Euhoploceras		

Zemistephanus carlottensis Normannites crickmayi Chondroceras oblatum C. allani C. defontii	Stephanoceras itinsae Skirroceras camanoi Chondroceras oblatum Stephanoceras skidegatense Stephanoceras sp. Chondroceras defontii	Teloceras dowlingi T. crickmayi Chondroceras oblatum C. allani Stephanoceras itinsae		Stephanoceras Chondroceras	Dorsetensia aff. deltafalcata D. liostraca D. romani D. cf. complanata D tecta Stephanoceras cf. humphriesianum S nodosum Epalxites anceps Chondroceras submicrostomum Chondroceras sp. Chondroceras submicrostomum
Zemistephanus richardsoni Z. carlottensis Z. alaskensis Normannites cf. crickmayi Chondroceras allani C. cf. defontii Sonninia tuxedniensis Stephanoceras cf. palliseri Skirroceras kirschneri Emileia constricta Sonninia tuxedniensis Lissoceras cf. semicostulatum Strigoceras cf. languidum Stephanoceras cf. nodosum Stemmatoceras cf. triptolemus Parabigotites crassicostatus Normannites ? kialagvikensis Otoites ?filicostatus O. cf. contractus Emileia constricta Papilliceras cf. arenata Sonninia tuxedniensis Witchellia adnata W.? aguilonia Arkelloceras Bradfordia costidensa Lytoceras Holcophylloceras costisparsum Macrophylloceras Phylloceras cf. kunthi	Zemistephanus richardsoni Z. carlottensis Z. alaskensis Chondroceras sp.	Arkelloceras aff. mclearni Stemmatoceras aff. frechi Kumatostephanus cf. turgidulum	Dorsetensia oregonensis Pelekodites dobsonensis Poecilomorphus cf. varius Chondroceras allani Sphaeroceras sp. Normannites orbignyi N crickmayi Stephanoceras aff. nodosum Skirroceras kirschneri Dorsetensia oregonensis Sphaeroceras Skirroceras kirschneri Stephanoceras Dorsetensia subtexta D. cf. edouardiana D. oregonensis Pelekodites silviesensis Skirroceras kirschneri Stephanoceras Asthenoceras delicatum Papilliceras stantoni Witchellia connata Dorsetensia pulchra D cf subtexta D. edouardiana D. oregonensis Pelekodites silviesensis Emileia buddenhageni Otoites contractus Normannites cf. densus N. crickmayi Stephanoceras mowichense Skirroceras juhlei Phaulostephanus oregonense Parabigotites crassicostatum	Dorsetensia aff. edouardiana D. blancoensis D mendozai Sonninia alsatica Papilliceras espinazitensis Otoites cf. gottschei Emileia multiformis E. contracta E. aff. polyschides Chondroceras cf. giebeli C. ex. gr. defontii C. cf. allani Sonninia? ovalis S. alsatica Skirroceras cf. macrum Dorsetensia aff. edouardiana D. mendozai D. blancoensis Pseudotoites cf. transatlanticus Witchellia Euhoploceras Stephanoceras ex. gr. nodosum Bradfordia Fissilobiceras cf. zitteli	Emileia multiformis E. multifida Otoites contractus Chondroceras aff. defontii Poecilomorphus subdeltafalcata Papilliceras espinazitensis
			Asthenoceras delicatum Papilliceras stantoni Witchellia connata Dorsetensia subtexta D. cf. complanata Pelekodites silviesensis Emileia Stephanoceras	Pseudotoites transatlanticus P. cf. sphaeroceroides P. cf. singularis Latotoites cf. evolutum Papilliceras espinazitensis P. cf. peruana Euhoploceras amosi Puchenquia malarguensis Fissilobiceras zitteli Sonninia mirabilis S. zitteli Bradfordia cf. costidensa B. cf. helenae	Sonninia altecostata Pseudotoites sphaeroceroides Sonninia adicra Pseudotoites singularis Latotoites evolutus Sonninia cf. crassispinata S. cf. ovalis S. argentinica
			Asthenoceras delicatum Papilliceras stantoni Witchellia connata Stephanoceras Asthenoceras delicatum Fontannesia costula F. intermedia F. cf. luculenta F cf. carinata Euhoploceras modesta E. dominans E. polyacantha E. adicra E. crassispinata Lativitchellia evoluta Pelekodites webergi Praestrigites cf. deltotus Docidoceras warmeringsense D. sparsicostum Stephanoceras nodosum Skirroceras juhlei S. dolichoecus		

proposed by Mouterde et al (1971, pp. 9-13) for France, and by Parsons (1974, Table 1, p. 154) and Morton (1975, Table 1, p. 43) for Great Britain. Table 2 shows a suggested correlation of Lower Bajocian ammonite faunas from the western Americas with those from selected areas of western Europe (excluding the lowermost Discites Zone).

4.2 BRITISH COLUMBIA

4.2.1 Queen Charlotte Islands

4.2.1a Previous Work

Early geological exploration of the Mesozoic formations of Skidegate Inlet was prompted by commercial interests in the coal-bearing rocks of the area. J. Richardson first examined the broad synclinal structure along the Inlet and nearby islands in 1872 and divided the rocks into three horizons (Table 3). Believing the shales on several islands to represent the same geological horizon he did not think it necessary to maintain separate fossil collections (Whiteaves, 1876, p. 6). In describing these fossils Billings (1873) inferred that more than one fauna was present. Whiteaves (1876, pp. 87, 88) also noted "an apparent mixture of Oolitic and Cretaceous types". He recognised that such forms as *Ammonites Richardsoni*, *A. Carlottensis*, *A. Skidegatensis* and *A. Loganianus* forms A and B resembled "Oolitic" forms from England (Middle-Upper Jurassic), but added that this similarity "is often of a very general character and can scarcely in any case be shown to amount to actual specific identity" (p. 91). Among Richardson's specimens were several species known to be Cretaceous and so Whiteaves (p. 9) concluded that only one fauna was present and that it represented "a blending of the life of the Cretaceous period with that of the Jurassic".

The failure of Richardson to separate Cretaceous rocks (now Haida Formation) from Jurassic rocks (now Yakoun Formation) and the continued insistence by Whiteaves (1876, 1884, 1900) that only one fauna was present confused later workers.

More extensive work by Dawson (1880) resulted in division of the "Cretaceous" sequence into five units (Table 3). Whiteaves (1884) described the fossils collected by Dawson and again noted four ammonites from the "lower shales" (Unit C of Dawson) that he stated would be regarded as Jurassic in Europe: *Ammonites Richardsoni*, *Stephanoceras oblatum* [= *Ammonites Loganianus* form A], *S. cepoides* [= *Ammonites Loganianus* form B] and *Perisphinctes Skidegatensis*. However, the association in the collection of these and known Cretaceous forms again led Whiteaves (1884) to suggest a lower Middle Cretaceous age. Stanton and Martin (1905) noted the resemblance of early Middle Jurassic fossils from southern Alaska to certain forms in the "lower shales" of the Queen Charlotte Islands; they believed the latter to have no connection with the Cretaceous faunas supposed to occur in the same formation.

In 1889 Dawson distinguished his Units C, D and E as the Queen Charlotte Islands Formation, believing them to represent a continuous sequence which rested unconformably on older (probably Triassic) rocks.

RICHARDSON 1873	DAWSON 1880, 1889		ELLS 1906	CLAPP 1914		MACKENZIE 1916	SUTHERLAND BROWN 1968		
upper shale and sandstone		upper shales and sandstone 1500' A		Queen Charlotte Series	Skidegate member		Queen Charlotte Gp	Skidegate Formation 2000'	
coarse conglomerate		conglomerate 2000' B			Honna member			Honna Formation 1300-1400'	Turonian ? Cenomanian
lower shale with coal and iron ore	Queen Charlotte Islands formation	lower shales and sandstones with coal 5000' C			Haida member			Haida Formation 3800'	Cenomanian Albian
								Longarm Formation 4000'	Barremian Hauterivian late Valanginian
		agglomerates 3500' D			Image Member	Yakoun Formation	Vancouver Gp	Yakoun Formation 3000-6000'	Lower Callovian Lower Bajocian
		lower sandstone 1000' E		Vancouver Gp		Maude Formation		Maude Formation 600'	Toarcian Pliensbachian late Sinemurian

Table 3. Stratigraphic subdivisions and ages of Jurassic-Cretaceous rocks of Skidegate Inlet area, Queen Charlotte Islands, as used by various authors. Heavy line represents position of Jurassic-Cretaceous boundary.

Unit D was separated from the overlying coal-bearing beds by Ells (1906) and given a pre-Cretaceous age. However, Clapp (1914) extended the Queen Charlotte Series to include Unit D, believing it to be a basal conglomerate of local development, conformable with the overlying Units, but resting unconformably on "metamorphic volcanic rocks which seem to belong to the Vancouver Group" (p. 12). Argillites and sandstones, shown by field relations to lie unconformably below the Queen Charlotte Series, were presumed to be of Jurassic or Triassic age. Clapp formally named the Skidegate, Honna and Haida Members for Dawson's subdivisions A, B and C.

The Jurassic strata of Skidegate Inlet were finally distinguished as two formations by MacKenzie (1916): the lower Maude Formation (Dawson's Unit E) and the overlying Yakoun Formation (Dawson's Unit D and those parts of Unit C which contained Jurassic fossils). MacKenzie recognised that the strong lithological similarities between the Cretaceous Haida Formation and parts of the Jurassic Yakoun Formation had been responsible for Dawson's failure to separate them and the faunas they contained. He stressed the importance of the unconformity between these two Formations.

Detailed mapping and careful collecting with attention to stratigraphy by McLearn in 1921 led to the recognition of several faunal horizons within the Jurassic formations of Skidegate Inlet. His descriptions of the stratigraphy and ammonite faunas of the Yakoun

FORMATION	DESCRIPTION		AGE
Haida			Albian (Lower Cretaceous)
Yakoun	E member	140 m, interbedded massive greenish volcanic sandstone with pebbly beds and grey shales and siltstones.	Callovian (upper Middle Jurassic)
	D member	240 m, dominantly fine crystal lithic tuffs with minor volcanic sandstone.	
	C member	290 m, coarse, porphyritic andesite and conglomerate.	
	B member	30 m, interbedded shales and tuffaceous sandstones.	Bajocian (lower Middle Jurassic)
	A member	200 m, fine porphyritic andesite agglomerate and tuffs with white calcareous cement.	
Maude			Toarcian (Lower Jurassic)

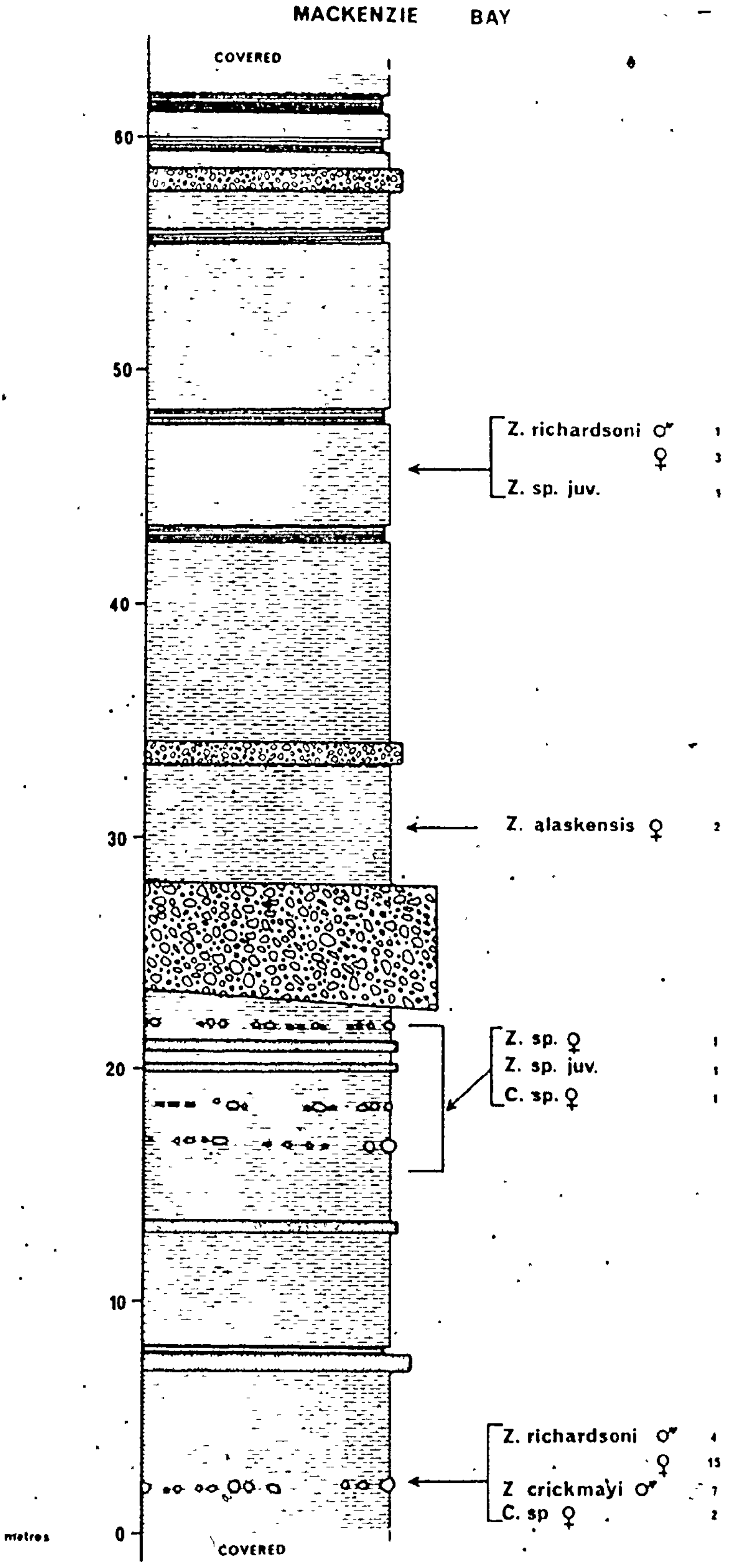
Table 4. Stratigraphy of the Yakoun Formation in the type section along the south-eastern shore of Maude Island, Skidegate Inlet, Queen Charlotte Islands (modified after Sutherland Brown, 1968).

Formation (McLearn, 1927, 1929, 1932, 1949) led to the distinction of two faunas: the Lower Yakoun or *Stephanoceras* fauna of Lower Bajocian age and the Upper Yakoun or "*Seymourites*" fauna of Lower Callovian age, separated by a thick sequence of unfossiliferous volcanic agglomerates and tuffs. A detailed section along the southern shore of Maude Island from Richardson Bay to Robber Point was recorded; it has recently been re-measured and designated the type section for the Yakoun Formation by Sutherland Brown (1968, pp.68, 72, 73).

4.2.1b Stratigraphy and Faunas

The Yakoun Formation is comprised of a great variety of rocks ranging from massive volcanic agglomerates and tuffs to volcanic sandstones, shales and siltstones. The type section on the southeastern shore of Maude Island is about 915 m. thick and has been subdivided into five members (Sutherland Brown, 1968, p. 73; Table 1, pp. 38, 39). These subdivisions are summarised in Table 4.

The rocks present in any one section of the Yakoun Formation vary considerably. Sutherland Brown (1968, Fig. 10, p. 67) has delineated a "facies front" which marks the zone of transition from dominantly volcanic agglomerate in the east to tuffs, volcanic sandstones and shales in the west. The type section is in this zone of transition so that all lithologies are present in abundance. Clastic rocks in the sequence are composed predominantly of fragments derived from porphyritic andesite. The agglomerates, tuffs and lapilli tuffs contain mainly blocks and



Text-fig. 2. Measured section, lower part of the Yakoun Formation, MacKenzie Bay. The numbers of identified ammonoids collected at various horizons are indicated to the right of the column.

▥ argillites

▤ shales, mudstones

▒ sandstone

▨ agglomerate

○ concretions

fragments of porphyritic andesite, about 20% crystal fragments and 20% fine matrix which is usually considerably altered. Related conglomerates are also composed almost entirely of rounded volcanic rock fragments. The volcanic sandstones are made up of subangular fragments of porphyritic andesite and angular crystal fragments in a chloritic matrix.

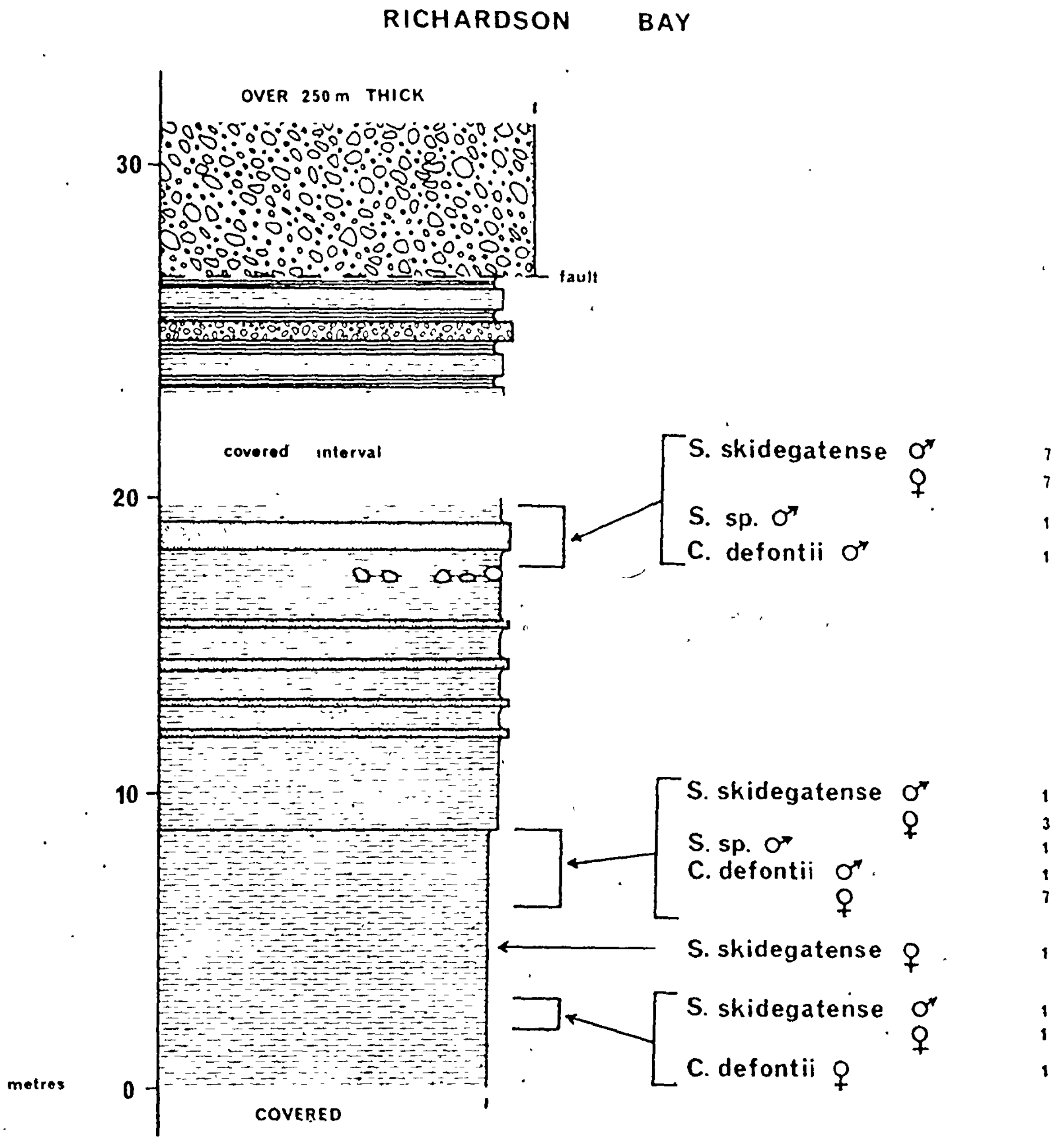
Sutherland Brown (1968, pp. 75, 76) envisaged the agglomerates and tuffs originating from a series of vents along a line on the eastern edge of the Islands. Pulses of volcanic activity were separated by periods of marine sedimentation with redistribution of volcanic detritus in a shallow, neighbouring sea. The abundance of leaves, fruit and wood fragments in some of these marine strata points to the proximity of a vegetation-covered land surface while a period of non-marine accumulation has resulted in the formation of coal beds within the volcanic sandstones of the Yakoun River valley.

McLearn (1949) reviewed the ammonites from the Lower Yakoun or *Stephanoceras* fauna from three localities (MacKenzie Bay, Richardson Bay and South Balch Island) which all lie within the shales and sandstones of Sutherland Brown's B member. The initial part of my study consisted of detailed measuring and collecting from each of these three localities (Text-fig. 1) and the results of this work are outlined below. The detailed stratigraphy and faunas at each of these fossiliferous localities are shown in Text-figs. 2-4.

MacKenzie Bay (Text-fig. 2). - Both the upper and lower boundaries of the B member are covered by Recent beach deposits. The basal part of the exposed section consists of just over 7 m of fine, dark shales, highly fragmented and with many small (2-6 cm in diameter), hard, rounded or elongated calcareous concretions. Several thin bands of grey-green sandstone show graded bedding. From one horizon near the base (only exposed at low tide) come large, rounded calcareous concretions, 10-15 cm in diameter, about half of which contain specimens of *Zemistephanus richardsoni* (Whiteaves) ♀ & ♂ and Z. *crickmayi* (McLearn) ♂. *Chondroceras* sp., a few bivalves and belemnites were collected from the associated shales. Abruptly overlying the shales is a thin but very prominent bed (60 cm thick) of buff-coloured volcanic sandstone with some minor bands of angular lithic fragments. Scour-and-fill structures are abundant, with some cross-bedding, and load structures occur along the base of the unit.

The succeeding 15 m of grey shale with sandy interbeds are sparsely fossiliferous, having yielded single specimens of *Chondroceras* sp., *Zemistephanus* ♀ sp. and an unidentified stephanoceratid ammonite, with a few belemnites, bivalves and brachiopods. This unit is very well stratified with conspicuous bands of elongated calcareous concretions. Cutting unconformably across the top of these beds is a massive, wedge-shaped unit, 5 m thick, of green volcanic sandstone and agglomerate.

In the overlying 35 m of poorly-bedded grey, silty shale a few



Text-fig. 3. Measured section, lower part of the Yakoun Formation, Richardson Bay. Symbols explained in Text-fig. 2.

fossils were found at two horizons. From just 2 m above the agglomerate come several specimens of *Zemistephanus alaskensis* n. sp. ♀ and 15 m higher are additional specimens of *Z. richardsoni* (Whiteaves) ♀ & ♂ with rare bivalves, belemnites and some worm borings. Some grey-black argillite bands give the only evidence of stratification.

Taxa identified by previous workers from this locality are shown in Table 5, along with their usage in this thesis.

Richardson Bay (Text-fig. 3) - The base of the section is covered with Recent beach deposits. The lower 9 m consist of massive, poorly-bedded shales with some white felspar grains. From several broad and poorly-defined "horizons" come specimens of *Stephanoceras skidegatense* (Whiteaves) ♀ & ♂ and abundant *Chondroceras defontii* (McLearn) ♀ & ♂. There follow 7.5 m of grey, highly-fractured sandy shale with occasional thin bands of pebbly tuff and some lightly contorted bands of finer, yellowish-green tuff.

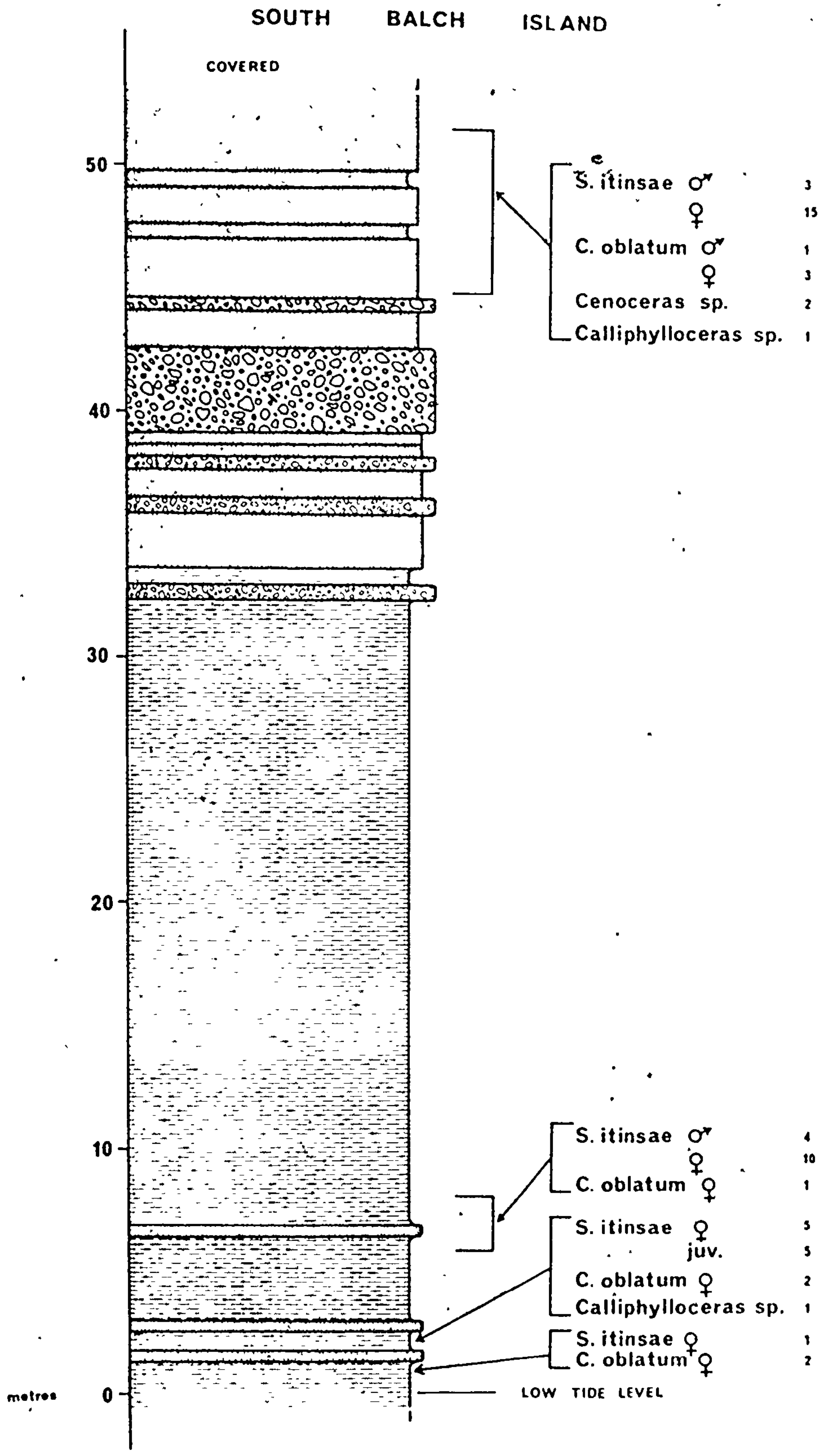
From the succeeding 3.5 m of dark, grey-brown shale additional specimens of *S. skidegatense* (Whiteaves) ♀ & ♂ and *C. defontii* (McLearn) ♂, some bivalves, gastropods and belemnites were collected. This unit also contains abundant hard, calcareous concretions of varying size and fragments of carbonized logs and branches.

Above a covered beach interval of 4 m is a thin succession of bands of alternating brown-grey sandy shales, blue-grey cherty argillite and agglomerates which are highly contorted and broken apart. These are faulted against massive brown, volcanic agglomerate containing some large blocks of the contorted sediments from below. This fault represents the base of the thick, massive agglomerate designated C member by Sutherland Brown (1968, p. 73).

Table 5 lists the ammonite species known from this locality and their revised taxonomy.

South Balch Island (Text-Fig. 4) - The western shore of this small island has an apparently continuous exposure of about 51 m through B member. Beginning on the southern shore is a sequence of 6 m of fine, grey shales with three prominent beds of grey-green sandstone all showing minor fault displacements. Fossils in this sequence include abundant *Stephanoceras itinsae* (McLearn) ♀ & ♂, some *Chondroceras oblatum* (Whiteaves) ♀ & ♂, bivalves, a few brachiopods and fossil fruit.

Next comes a barren, monotonous sequence of grey shales 25.5 m thick extending along the western shoreline and largely covered by loose boulders. It has yielded several bivalves and gastropods and some fossil fruit. Towards the top of the sequence massive volcanic agglomerate and sandstone become the dominant lithologies with a few interbeds of sandy shales, one of which again yielded the *S. itinsae* - *C. oblatum* fauna, along with single specimens of ?*Eutrephoceras* sp.,



Text-fig. 4. Measured section, lower part of Yakoun Formation, along southern and western shores of South Balch Island. Symbols explained in Text-fig. 2.

Cenoceras sp. and *Calliphylloceras* sp. and rare bivalves.

The eastern side of the island is a large fault block cut by several smaller faults. It is composed mostly of massive, coarse volcanic sandstones, grey-green and brown in colour. There are minor dark grey shales. Besides scattered specimens of *S. itinsae* (McLearn) ♀ & ♂, *C. oblatum* (Whiteaves) ♀ & ♂ and a single *Calliphylloceras* sp., these sandstones contain many large concretions with concentric internal layering, leaf impressions, fossil fruit, carbonized stems and wood fragments. Scattered throughout the strata on both sides of the island are irregular accumulations, 10-30 cm across, of darker shale containing a concentration of broken ammonite fragments, small bivalve shells and gastropods. Their origin remains unknown.

4.2.1c Summary

It is clear from the faunal lists of the three fossil localities in the lower Yakoun Formation (Table 5) that three distinct and separate faunas are present; the problem of their relative ages now arises. Although the section at each locality is thick and apparently continuous, no specimen representing the other two faunas has been found in stratigraphic succession at any locality. McLearn (1949) believed that these three faunas were "apparently all of one fauna, the lower Yakoun or *Stephanoceras* fauna" (p. 16). Imlay (1964, p. B19) also held that the "various species of *Chondroceras, Normannites* and *Teloceras* that were obtained from these localities on Maude Island occur together in the Fitz Creek Siltstone in Alaska and belong to a single faunule". However, as discussed elsewhere (pp. 41, 42) the various species of these genera are stratigraphically segregated in the Fitz Creek Siltstone.

In reviewing these faunas for comparison with Bajocian faunas from Western Australia, Arkell (1954) transferred *Ammonites carlottensis* Whiteaves to *Pseudotoites* believing it to resemble closely the Australian *P. leicharti* (Neumayr). However, the characters of the mature body chamber, septum and suture have resulted in this species being placed in the genus *Zemistephanus* McLearn (p. 81). On paleontological grounds Arkell (1956, p. 542) suggested that the fauna from MacKenzie Bay was distinct from, and older than, the Richardson Bay fauna.

<u>MacKenzie Bay</u> - The small, septate holotype and one other septate specimen of *Teloceras itinsae* McLearn from this locality were both collected as float and so have no biochronological value. Supposed *Normannites* [=*Kanastephanus*] are here recognised as microconch *Zemistephanus*. The *Zemistephanus* fauna from this locality corresponds very closely in composition with that from the Fitz Creek Siltstone in southern Alaska (discussed on p. 92). Species in common are: *Z. richardsoni* (Whiteaves) ♀ & ♂; *Z. carlottensis* (Whiteaves) ♀ ; *Z. crickmayi* (McLearn) ♂; and *Z. alaskensis* n. sp. ♀ . Species of *Chondroceras* are also present in both faunas.

Due to discontinuity of outcrop the stratigraphic positions of

PREVIOUSLY IDENTIFIED TAXA		HERE
1. MacKenzie Bay		
Zemistephanus richardsoni (Whiteaves) *Z. funteri* McLearn	......	*Zemistephanus richardsoni* (Whiteaves) ♀
	......	*Z. richardsoni* (Whiteaves) ♂**
Z. carlottensis (Whiteaves) *Z. vancouveri* McLearn	......	*Z. carlottensis* (Whiteaves) ♀
	......	*Z. alaskensis* n. sp. ♀ **
Normannites (Kanastephanus) crickmayi (McLearn) *N. (K.) canadensis* (McLearn) *N. (K.) altus* (McLearn) *N. (K.) mackenzii* (McLearn)	......	*Z. crickmayi* (McLearn) ♂
Teloceras itinsae McLearn	......	*Teloceras itinsae* McLearn ?♀
	......	*Chondroceras* n. sp. indet. **
2. Richardson Bay		
Stephanoceras skidegatense (Whiteaves) *S. skidegatense* var. *laperousii* McLearn	......	*Stephanoceras skidegatense* (Whiteaves) ♀
	......	*S. skidegatense* (Whiteaves) ♂**
	......	*S.* sp. ♂ aff. *S. skidegatense* (Whiteaves) ♂**
Chondroceras (Defonticeras) defontii (McLearn) *C. (D.) colnetti* (McLearn) *C. (D.) ellsi* (McLearn) *C. (D.) marchandi* (McLearn)	......	*Chondroceras defontii* (McLearn) ♀
	......	*C. defontii* (McLearn) ♂**
C. (D.) maudense (McLearn)	......	*C. maudense* (McLearn) ♀
3. South Balch Island		
Stephanoceras yakounense McLearn	......	*Stephanoceras itinsae* (McLearn) ♀
Normannites (Itinsaites) itinsae (McLearn)	......	*S. itinsae* (McLearn) ♂
Stephanoceras caamanoi McLearn	......	*S. caamanoi* McLearn ♀
	......	*Calliphylloceras* sp. indet. **
	......	?*Eutrephoceras* sp. indet. **
	......	*Cenoceras* sp. indet. **
Chondroceras (Defonticeras) oblatum (Whiteaves)	......	*Chondroceras oblatum* (Whiteaves) ♀
	......	*C. oblatum* (Whiteaves) ♂**

Table 5. List of previously recognised, revised and new taxa from the lower part of the Yakoun Formation.
** indicates species described here for the first time.

these beds relative to those at Richardson Bay and on South Balch Island cannot be established. The only clue to the relative ages of the contained faunas is a small ammonite nucleus (GSC 13636; Pl. 7, fig. 4) which, according to McLearn's handwritten label was collected by him between MacKenzie and Maude Bays on the north shore of Maude Island. This locality description corresponds to the uppermost part of the section shown for MacKenzie Bay in Text-fig 2, i.e. stratigraphically above the *Zemistephanus* horizons. No further material has been recovered from this part of the section. This nucleus bears a very strong resemblance to a specimen of similar size (McM J1802f; pl. 7, fig. 5) collected by me about 20 m above the exposed base of the section at Richardson Bay. This is undoubtedly the nucleus of *Stephanoceras skidegatense* (Whiteaves) (♀ or ♂), other more complete specimens of which occur in the same bed. A detailed analysis of similar faunas within the Fitz Creek Siltstone and Cynthia Falls Sandstone of southern Alaska (pp. 39-42) also suggests that the *Zemistephanus* fauna is older than those from Richardson Bay and South Balch Island which contain abundant *Stephanoceras* but no *Zemistephanus*.

<u>Richardson Bay</u> - The Richardson Bay fauna is characterised by abundant *Chondroceras defontii* (McLearn) ♀ & ♂ and *Stephanoceras skidegatense* (Whiteaves) ♀ & ♂, while *Zemistephanus* is unknown. In southern Alaska *C. defontii* ♀ ranges through most of the Fitz Creek Siltstone where it is associated with *Zemistephanus* and persists into the overlying Cynthia Falls Sandstone where *Z. richardsoni* is absent and

C. oblatum ♀ first appears. It is suggested that the *S. skidegatense* faunule is probably younger than the *Z. richardsoni* faunule.

South Balch Island - *Stephanoceras itinsae* (McLearn) ♀ from this locality is very similar to European species of the *S. umbilicum* - *S. mutabile* group; these forms in western Europe first appear and reach maximum numbers in the middle and upper parts of the Humphriesianum Subzone (Schmidtill and Krumbeck, 1938; Mouterde et al, 1971). *S. itinsae* ♀, which is so abundant in the Bajocian faunas of the Queen Charlotte Islands and Alberta, is not known from the thick sequences of southern Alaska where the *Zemistephanus* faunule is dominant. However, *Stephanoceras obesum* Imlay from the Tuxedni Formation in the Talkeetna Mountains of southern Alaska (Imlay, 1964, pp. B45, 46; Pl. 18, figs. 5-11) is a similar form (p. 128). In the Cynthia Falls Sandstone of southern Alaska, however, *Chondroceras oblatum* (Whiteaves) occurs with an undescribed *Stephanoceras* sp. (Imlay, 1964, Table 7). *Chondroceras* cf. *oblatum* (Whiteaves) and *C. defontii* (McLearn) are listed from the Cynthia Falls Sandstone (Table 7), but they do not occur at the same locality, a feature also noted in the lower Yakoun Formation. Whether such segregation is due to some ecological factor or difference in age of the faunas is not clear.

It is tentatively concluded that the *S. itinsae* - *C. oblatum* faunule from South Balch Island is younger than the *Zemistephanus* faunule at MacKenzie Bay and belongs to the middle and upper parts of the Humphriesianum Subzone of Europe (Table 2).

4.2.2 Southern Mainland

Faunas described from Manning Park and the Taseko Lakes area of south-western British Columbia provide further evidence of Lower Bajocian Strata (Frebold et al, 1969); ammonite species well known from southern Alaska, the Queen Charlotte Islands and southern Alberta are present.

The Lookout Section in the Eastern Jurassic Belt at Manning Park consists of coarse to medium grained volcaniclastic sediments with lesser amounts of marine clastics and massive lavas. Because of numerous transverse and strike faults within this section (Coates in Frebold et al, 1969, p. 3) the sequence of ammonite faunas can have little stratigraphic significance. Otoitidae, *Stephanoceras* cf. *S. caamanoi* McLearn and *Chondroceras* spp. represent faunas belonging to the Sauzei and Humphriesianum Zones. The reported *Zemistephanus richardsoni* is not conspecific with McLearn's species (p. 82).

Stephanoceras (Skirroceras) cf. *S. kirschneri* Imlay, associated with *Witchellia*, in the Taseko Lakes area represents the Sauzei Zone; *Chondroceras "marshalli"* (McLearn) occurs elsewhere in this area, indicating strata of probable Humphriesianum Zone age (Frebold et al, 1969, pp. 18, 19).

4.3 ALBERTA

4.3.1 Previous Work

Jurassic rocks ranging in age from Sinemurian to Upper Portlandian comprise the Fernie Group which has been mapped extending from southernmost Alberta over 1,000 km to the north in the Peace River area (Frebold, 1957, pp. 1, 2; Frebold and Tipper, 1969, pp. 9, 10; Fig. 6). The section is incomplete with many hiatuses indicated by the absence of index fossils.

Warren (1934) proposed the name Rock Creek Member for a marker horizon 15-45 m above the base of the Fernie Group. The unit is a calcareous sandstone bed, 1.5-9 m thick with a rich and distinctive Lower Bajocian fauna consisting mainly of stephanoceratid ammonites, belemnites and bivalves. In his extensive review of the Fernie Group Frebold (1957, p. 14) pointed out that the typical calcareous sandstone of the type locality was often replaced in other areas by sandy shales and that its diagnostic fauna (referred to as the *Teloceras* fauna) also occurred in shales with concretions below the typical Rock Creek Member. Frebold proposed use of the name Rock Creek Member sensu lato for all beds containing the "*Teloceras* fauna".

Ammonites from numerous localities supposedly representing the "*Teloceras* fauna" of Lower Bajocian age, which have been described and figured by Warren (1947), McLearn (1927, 1928, 1930, 1932b) and Frebold (1957), are listed in Table 6.

Evidence for the existence of more than one faunal horizon in the Rock Creek Member (apart from the closely associated beds with *Sonninia* discussed by Frebold, 1957, pp. 13, 15) was discussed by Westermann (1964b, pp. 405-7). The occurrence of *Arkelloceras* n. sp. with *Stemmatoceras* sp. aff. *S. frechi* Renz and *S. (Kumatostephanus)* sp. cf. *S. turgidulum* (Quenstedt) one foot below the upper sandstone bed in the Snake River section (see Frebold, 1957, p. 92) led Westermann to place this fauna in the Sauzei Zone.

4.3.2 Stratigraphy and Faunas

Ribbon Creek - The only fossil locality in the Rock Creek Member to which the writer had access during the field season of 1971 was that in Ribbon Creek, southern Alberta. Details of this section were given by Frebold (1957, pp. 81, 82). New collections made by myself and G.E.G. Westermann (in the McMaster University collections) have been studied.

The best preserved and most abundant forms at this locality are *Chondroceras allani* (McLearn) ♀ and *C. marshalli* (McLearn) ♀ [= *C. oblatum* (Whiteaves) ♀]. *Zemistephanus crickmayi* Frebold (Frebold, 1957, pp. 52, 53; Pl. XXV; Pl. XXVI; Pl. XXVII) is here referred to the genus *Teloceras* (p. 169) and several other larger, fragmentary specimens in the McMaster University collections also represent this genus. The holotype of *Teloceras dowlingi* McLearn is also assumed by Frebold (1957, p. 52) to have come from this locality. The specimen described in detail by Frebold (1957, pp. 50, 51; Pl. XXI, figs. 2a, b; Pl. XXIII, figs 1a-c)

LOCALITY	FAUNA
Sheep River	*Stemmatoceras albertense* McLearn *S. carri* Warren *Chondroceras allani* (McLearn) *C. marshalli* (McLearn) *C.* spp.
Kananaskis Valley	*Teloceras dowlingi* McLearn
Porcupine Creek (Kananaskis Valley)	*Teloceras warreni* McLearn
Whitehorse River (Mountain Park area)	*Stemmatoceras palliseri* McLearn *S. carri* Warren *Teloceras stelcki* Warren
Livingstone Gap	*Stephanoceras* ex. gr. *skidegatense* (Whiteaves) *Chondroceras* sp.
Snake Indian River	*Stephanoceras* ex. gr. *skidegatense* (Whiteaves) *Stephanoceras* sp. indet. *S. (Kumatostephanus)* sp. cf. *S. turgidulum* *S. (Stemmatoceras)* sp. aff. *S. frechi* *Arkelloceras* n. sp.
Ribbon Creek	*Stemmatoceras albertense* McLearn *Zemistephanus crickmayi* Frebold *Chondroceras allani* (McLearn) *C. marshalli* (McLearn)
Miners Creek (Cadomin)	*Stemmatoceras mclearni* Warren
Stoney Creek-Highwood River-Sheep River area	*Stemmatoceras mclearni* Warren *Teloceras allani* Warren
Folding Mountain	*Stephanoceras* cf. *skidegatense* (Whiteaves)
no localities given	*Zemistephanus ?* *Itinsaites ?* *Kanastephanus ?*

Table 6. List of ammonites described or identified from the Rock Creek Member of western Alberta by various authors.

as *Stemmatoceras albertense* McLearn is believed to be another *Stephanoceras itinsae* (McLearn) ♀ (pp. 126-7); other fragmentary material from this locality is also identified with this species (Pl. 6, fig. 1). The corresponding microconch ("*Itinsaites itinsae*" McLearn) has also been collected from the Ribbon Creek locality (McM J 1838; Pl. 7, fig. 1) along with numerous stephanoceratid nucleii which possibly also represent this species.

The occurrence of *S. itinsae* ♀ & ♂ and *C. oblatum* ♀ together in this bed indicates it is correlative with the lower Yakoun Formation exposed on South Balch Island (p. 30). The presence of several macroconch *Teloceras*, but no *Zemistephanus*, suggests correlation with the upper parts of the Humphriesianum Subzone of western Europe. Early *Teloceras*, with narrower and less coronate whorl sections, are already reported in this Subzone in France (Mouterde et al, 1971, pp. 11, 12) and in England (Parsons, pers. comm.).

Snake Indian River - Faunas representing two horizons of different age seem to be present in the section of the Rock Creek Member s. l. exposed in Snake Indian River valley. *Stephanoceras* ex. gr. *skidegatense* described by Frebold (1957, pp. 49, 50; Pl. XXII, fig. 2; Pl. XXV, fig. 2) is believed to be *S. itinsae* (McLearn) ♀ (p. 127). Unfortunately the exact stratigraphic horizon from which this specimen was collected is not recorded; "stephanoceratids" occur at several horizons in this section (Frebold, 1957, p. 92). Westermann (1964b,

p. 407) believed that the faunule with *Arkelloceras* n. sp. aff. *A. mclearni*, which he correlated with the Sauzei Zone, probably came from the same level as Frebold's described specimen. The specimens referred to *Kumatostephanus* by Westermann (1964b) are a fragment of body chamber about 8 cm in length which closely resembles the body chamber of *Skirroceras nelchinanum* Imlay from southern Alaska and another (body chamber?) resembling a single whorl described from this same locality by Frebold (1957, p. 50; Pl. XXII, figs. 1a, b) as *Stephanoceras* sp. indet. A Sauzei Zone age for *Arkelloceras* is supported by Imlay's correlation (1964, pp. B53, 54) with the Zone of a fauna containing *Arkelloceras* ? sp. juv. from the Kialagvik Formation at Wide Bay in southern Alaska.** However, the occurrence of several specimens representing the genus *Teloceras* with *S. itinsae* (McLearn) ♀ & ♂ in the fauna from Ribbon Creek suggests correlation of that fauna with the Humphriesianum Subzone (p. 30). Thus it is confirmed that two faunas are present in the Snake Indian River section: the *Arkelloceras* faunule from the Sauzei Zone and the *Stephanoceras itinsae* faunule from the Humphriesianum Zone (and Subzone).

<u>Other Localities</u> - Ammonites from many localities within the Rock Creek Member s. l. (Table 6) give evidence of the widespread occurrence of the supposed "*Teloceras* fauna". Further collections in the Department of Geology, University of Alberta, Edmonton from Cadomin, Luscar, Mountain Park, and the Whitehorse and Highwood River areas of the Alberta Rockies contain fragments representing *Chondroceras* spp. and both macroconch and

microconch stephanoceratids. Wide geographical separation of these localities and lack of faunal sequences make it impossible yet to establish any biochronological subdivisions within the Rock Creek Member, but as suggested above these specimens probably represent more than a single fauna.

4.4 ALASKA

4.4.1. Previous Work

Detailed descriptions of Lower Bajocian (Sauzei and Humphriesianum Zones) ammonite faunas from the Cook Inlet region and the Talkeetna Mountains of southern Alaska were published by Imlay (1964). Material on which these descriptions were based had been collected by numerous geologists between 1904 and 1958 from the Tuxedni Group and the Tuxedni Formation. The Lower Bajocian part of the Tuxedni Group along the northwest side of Cook Inlet contains four units which are of great, but very variable, thickness: the Red Glacier Formation, Gaikema Sandstone, Fitz Creek Siltstone and Cynthia Falls Sandstone (Imlay, 1964, Table 2). Characteristic fossils and suggested guide fossils for these units and their correlation with the Standard Zones of North-West Europe are summarised in Table 7.

Along the Alaskan Peninsula to the south-west, Bajocian faunas correlated with the "Sowerbyi" and Sauzei Zones have been described by Westermann (1969). At the top of the Kialagvik Formation is an ammonite fauna which is correlated with the *Parabigotites* faunule from the top of the Red Glacier Formation (Westermann, 1969, p. 22; Imlay, 1964, pp. B18,

FORMATION	CHARACTERISTIC FAUNA	SUGGESTED GUIDE FOSSILS	ZONE
Cynthia Falls Sandstone	*Teloceras itinsae* McLearn	*Teloceras itinsae*	Humphriesianum
	Zemistephanus richardsoni (Whiteaves)		
	Z. carlottensis (Whiteaves)		
Fitz Creek Siltstone	*Normannites (Itinsaites) crickmayi* (McLearn)		
	N. (I.) itinsae (McLearn)		
	Chondroceras defontii (McLearn)		
	C. allani (McLearn)		
	C. cf. *C. oblatum* (Whiteaves)		
Gaikema Sandstone	*S. (Skirroceras) kirschneri* Imlay	*Skirroceras kirschneri*	Sauzei
	S. (Skirroceras) juhlei Imlay		
Red Glacier Formation	*Parabigotites crassicostatus* Imlay	*Parabigotites crassicostatus*	
	Normannites kialagvikensis Imlay		
	Witchellia adnata Imlay		
	Sonninia tuxedniensis Imlay		
	S. (Papilliceras) cf. *S. (P.) arenata* (Qu.)		
	Otoites cf. *O. contractus* (Sowerby)		
	Emileia constricta Imlay		
	Bradfordia? caribouensis Imlay		

Table 7. Characteristic ammonite faunas, suggested guide fossils and Zonation for part of the Tuxedni Group along the north-west side of Cook Inlet, southern Alaska (from Imlay, 1964).

19).

4.4.2 Stratigraphy and Faunas

Correlation of the richly fossiliferous Bajocian sequences of the Cook Inlet region and Talkeetna Mountains with the Standard European Zones is hampered by the scarcity of Sonniniidae (especially *Dorsetensia, Sonninia* and *Poecilomorphus*) above the Red Glacier Formation and of the familiar Stephanoceratidae so common in the Sauzei and Humphriesianum Zones of Europe (i.e. *Stephanoceras*, "*Stemmatoceras*", "*Normannites*" and *Teloceras*). The great thicknesses (180-1200 m) of these sequences of massive silty shales, sandstones and greywackes with some massive conglomerates make detailed litho- and biostratigraphy difficult. Formations vary tremendously in thickness from one locality to another and are disrupted by major thrust faults (Imlay, 1964, pp. B6-10).

The upper parts of the Red Glacier Formation were correlated with the upper Sauzei Zone because *Normannites* and *Chondroceras* are not known from below this level (Imlay, 1964, p. B12). The specimens of *Chondroceras* cf. *C. defontii* (McLearn) listed as occurring in the Red Glacier Formation were not obtained in situ (Imlay, 1964, p. B12) and the reported species of *Normannites* are now referred to other genera: *Normannites kialagvikensis* Imlay is the microconch of *Parabigotites crassicostatus* Imlay (cf. Imlay, 1973, pp. 32, 85, 95; both are restricted to the Red Glacier Formation where they usually occur together) and *Normannites (Itinsaites) crickmayi* (McLearn) is a microconch form of *Zemistephanus* (p. 99).

Both macroconch and microconch representatives of *Chondroceras* have been recently reported from the Laeviuscula Zone in southern England (Parsons, 1974, p. 167). Thus the constraints which led Imlay to suggest correlation of this fauna with the upper part of the Sauzei Zone are no longer operative.

Higher in the Red Glacier Formation *Stephanoceras (Skirroceras) kirschneri* Imlay is the dominant species and is not associated at any of the listed localities with *P. crassicostatus* Imlay ♀ & ♂. The close similarity of *S. kirschneri* to the more evolute European *Stephanoceras* spp. suggests correlation of this upper faunule with the Sauzei Zone also.

The overlying Gaikema Sandstone, of which only the basal part is fossiliferous, contains *Emileia constricta* Imlay, *Bradfordia*? *caribouensis* Imlay, *Witchellia* sp. and *Sonninia (Papilliceras)* cf. *arenata* (Quenstedt). This fauna should also be correlated with the Sauzei Zone. *Witchellia* and *Papilliceras* are most abundant at the top of the "Sowerbyi" Zone in France (Mouterde et al, 1971, p. 11) and occur in the "Sowerbyi" and Sauzei Zones of western Europe and England (Parsons, 1974) and the Sauzei Zone of Chile and Argentina (for a discussion see Westermann and Riccardi, 1972a, pp. 73-77).

Due to the supposed presence of *Normannites* and *Teloceras*, the fauna of the Fitz Creek Siltstone was correlated with the Humphriesianum Zone (Imlay, 1964, p. B12). However, none of the figured *N. (It.)*

crickmayi (McLearn) and *N. (It.) itinsae* (McLearn) from this unit is a true *Normannites*; as shown elsewhere in this thesis (pp. 99-107) *N. (K.) crickmayi* and its allied forms are microconch *Zemistephanus*. The specimens figured under *N. (It.) itinsae* are likewise microconch *Zemistephanus*, as they show neither the rounded whorl section nor the persistence of dense secondary ribbing (three to each primary) right to the aperture, two features which characterise "*Itinsaites*" *itinsae* (here recognised as a microconch *Stephanoceras*). Material identified with *Teloceras itinsae* McLearn (Imlay, 1964, pp. B50, 51) does not exhibit features of mature *Teloceras* from Europe. The body chamber of the Alaskan specimens egresses strongly, is narrow with a rounded whorl section and highly arched venter but lacks both steep umbilical walls and strong nodes. These characters suggest that this material represents a coarsely-ribbed species of *Zemistephanus*, here renamed *Z. alaskensis* n. sp. (p. 107). The dominant ammonite species in the Fitz Creek Siltstone, *Z. richardsoni* (Whiteaves), is restricted to this unit and so is proposed as an appropriate guide fossil to replace "*Teloceras itinsae*" McLearn. The absence of any true *Stephanoceras* suggests correlation of the *Z. richardsoni* faunule with the Sauzei Zone or lowest Humphriesianum Zone.

Chondroceras defontii (McLearn), which forms a strong association with *Zemistephanus* throughout the Fitz Creek Siltstone, does not usually occur with *C. allani* (McLearn); they are reported together only once at USGS Mes. loc. 21276, which covers a stratigraphic interval of 10.7 m (Imlay, 1964, Table 6). *C. allani* does occur with *C.* cf. *oblatum*

(Whiteaves) which first appears at the base of the overlying Cynthia Falls Sandstone (Imlay, 1964, Table 8) and also with *C. marshalli* [= *C. oblatum*] in the Tuxedni Formation (Imlay, 1964, Table 12). *C. allani* and *C. oblatum* are found associated with undescribed *Stephanoceras* and *Stemmatoceras*, genera with which they commonly occur in the Queen Charlotte Islands and western Alberta (p. 35). It is suggested that this faunule represents a higher horizon than the *Z. richardsoni* - *C. defontii* faunule and may be correlated with the Humphriesianum Subzone.

4.5 OREGON

4.5.1 Previous Work

Bajocian rocks in east-central Oregon consist of sequences of marine clastics ranging from coarse conglomerates to siltstones and mudstones. Fragments are of volcanic origin and locally there are developments of andesitic lavas and volcanic breccias. These rocks vary in thickness from 335 m to 810 m (Imlay, 1973, p.8) and marked changes in both thickness and lithology over short distances mean that locally recognisable lithological members cannot be traced laterally for any great distance. Recognition of this limitation resulted in Dickinson and Vigrass (1965) using the term Snowshoe Formation of Lupher (1941) to include a number of lithological units previously recognised as Formations by Lupher. Thus the Snowshoe Formation in the Suplee area is divided into three easily recognisable units: the lowest Weberg Member, the Warm Springs Member and the upper Basey Member. Ammonite faunas and lateral continuity of some beds allow correlation of these units with the outcrop of the Snowshoe Formation in the Izee area where it is much thicker and includes strata both older and younger than in the Suplee area (Imlay, 1973, p. 9; Fig. 1).

Extensive collections of ammonites from the Bajocian strata of eastern Oregon have been described and figured by Imlay (1973). The contained faunas indicate that the Snowshoe Formation in the Izee area represents Toarcian to early Callovian while in the Suplee area it is mostly Lower Bajocian ("Sowerbyi" to Humphriesianum Zones) with marked hiatuses at its base and top. The basal Weberg Member unconformably overlies strata of Pliensbachian and Paleozoic ages while the uppermost Basey Member is separated from overlying Callovian strata by an unconformity representing Upper Bajocian and all of Bathonian time.

4.5.2 Stratigraphy and Faunas

A westward onlapping sequence of hard, sandy limestone and calcareous sandstone, 15-75 m thick, comprises the Weberg Member in the Suplee area. Ammonites, including *Tmetoceras scissum* (Benecke), *Praestrigites* and *Eudmetoceras* in the basal part of the Member, indicate correlation with the Concavum Zone while the middle and upper parts of the Member (with *Sonninia (Euhoploceras) modesta* Buckman and *Docidoceras lupheri* Imlay) are correlated with the Discites and Trigonalis Subzones of the "Sowerbyi" Zone (Imlay, 1973, pp. 20-22). These correspond to the Discites and Ovalis Zones respectively, as recognised herein (Table 1).

Correlation of the faunas in the overlying Warm Springs Member with the middle and upper parts of the "Sowerbyi" Zone and the Sauzei Zone is based on "the presence of *Witchellia* throughout the member, the end of occurrences of *Witchellia* and *Papilliceras* at its top, the presence of *Emileia* and *Dorsetensia* in its upper two thirds, the presence of *Normannites* near its top, and the presence of *Fontannesia* near its base" (Imlay, 1973, p. 22). This unit consists of soft, calcareous, thinly laminated claystones and mudstones, 30-90 m thick, and on the basis of faunal similarity may be correlated with the upper parts of the unnamed Lower Member in the Izee area. Here the Lower Member consists of 150-230 m of black and dark grey siltstone, claystone and mudstone with local developments of concretions and thin limestone beds (Imlay, 1973, p. 14). In the upper parts of the Warm Springs Member the diagnostic ammonites are *Parabigotites crassicostatus* Imlay, *Skirroceras juhlei* Imlay, *Witchellia connata* (Buckman), *Otoites contractus* (J. de C. Sowerbyi) and *Emileia buddenhageni* Imlay, all of which occur together in three collections made from USGS Mesoz. loc. 78 (Imlay, 1973, Table 6). This fauna correlates with the *Parabigotites*-faunule found in the upper parts of the Red Glacier Formation in southern Alaska (Imlay, 1964, Fig. 5) and is placed in the Sauzei Zone by Imlay (1973, Fig. 1, p. 10).

The overlying Basey Member in the Suplee area consists of massive units of volcanic fragmental rocks and interbedded andesitic lavas. It is 760 m thick but thins rapidly to the east, grading into finer clastic rocks which are placed in the Middle Member of the Snowshoe Formation in the Izee area. Here this unit is 305 m thick and consists of thinly bedded, dark grey and black calcareous siltstone and claystone with alternating grey and green sandy siltstone and fine sandstones of volcanic origin. Further east these beds intertongue with conglomeratic volcanic rocks of the Silvies Member (Imlay, 1973, p. 14). According to Imlay the lower part of the Basey Member (120-150 m) is characterised by ammonite species which range upwards from the Warm Springs Member (*Dorsetensia* cf. *D. subtexta* Buckman, *Pelekodites silviesensis* Imlay, *Skirroceras juhlei* Imlay and *Asthenoceras delicatum* Imlay) together with *Skirroceras kirschneri* Imlay and *Dorsetensia oregonensis* Imlay. The middle part of the unit has yielded few ammonites but in the upper part *Poecilomorphus varius* Imlay, *Chondroceras allani* (McLearn), *Normannites orbignyi* Buckman, *N. (Itinsaites) crickmayi* (McLearn). and *Stephanoceras* cf. *nodosum* (Quenstedt) are said to make their first appearance. The fauna of the lower part is correlated with the Sauzei Zone and that of the middle and upper parts with the Humphriesianum Zone (Imlay, 1973, p. 24). However, the occurrence together of *S. kirschneri* and *N. (It.) crickmayi* [= *Zemistephanus* ♂] near the top of the Basey Member again suggests correlation with the fauna of the upper Red Glacier Formation or lowermost Fitz Creek Siltstone in southern Alaska (Imlay, 1964, pp. B28-30) and the Sauzei Zone. *Pelekodites* in Europe seems to be restricted to the "Sowerbyi" and the lower Sauzei Zones (Pavia and Sturani, 1968; Parsons, 1974; Morton, 1975) while an abundance of serpenticone *Stephanoceras* (called *Skirroceras* by Imlay) is characteristic of the Sauzei Zone.

At a number of localities in the unnamed Middle Member of the Snowshoe Formation in the Seneca and Emigrant Creek areas ammonite faunas occur which are very similar in generic and even specific composition to those from the Fitz Creek Siltstone in southern Alaska (Imlay, 1973, Table 9). The recurring association of *S. kirschneri* - *S. juhlei* and "*N. crickmayi*" [= *Zemistephanus* ♂] - *Z. richardsoni* - "*T. itinsae*" [= *Zemistephanus* ♀] - *Chondroceras* without *Stephanoceras* spp. ♀ & ♂ and *Teloceras* ♀ which are so abundant in the faunas of the Humphriesianum Zone in British Columbia and Alberta again suggests that the *Zemistephanus* and *Skirroceras* faunules are older (i.e. lowermost Humphriesianum or Sauzei Zones).

Specimens identified as *Teloceras itinsae* McLearn by Imlay (1973, p. 90; Pl. 46, figs. 10, 11, 13) are too poorly preserved and fragmentary to allow confident placement in *Teloceras*; indeed, the nature of the primary ribbing and nodes is very similar to that seen on the phragmocene whorls of *Zemistephanus*. Microconch forms described as *Normannites* (*Itinsaites*) *crickmayi* (McLearn) (pp. 83, 84; Pl. 41, figs. 2-5), all laterally crushed, have ribbing and coiling indicative of *Zemistephanus* ♂ as discussed elsewhere in this thesis (p. 133). Specimens identified as *N. orbignyi* Buckman (pp. 82, 83; Pl. 41, figs. 9, 10, 18, 20), though apparently too fragmentary to allow detailed measurement, also closely resemble *Zemistephanus* ♂. Three specimens from a single locality (Lupher's 272) are compared with *N.* (*I.*) *itinsae* (Mclearn) (p. 48; Pl. 41, figs. 6-8) but are much smaller than that species and have stronger, more rounded nodes. "*N.* (*I.*) *itinsae*" [= *S. itinsae* ♂] has not been found elsewhere associated with the *S. kirschneri* - *S. juhlei* faunules, and species of *Pelekodites* and *Sonninia* which comprise the rest of the fauna at this locality suggest correlation with the Sauzei or Laeviuscula Zones. In British Columbia and Alberta *S. itinsae* ♀ & ♂ is associated with *Teloceras* spp. and *C. oblatum* (Whiteaves) and placed in the Humphriesianum Zone.

In addition to those species and genera already discussed which are in common with the MacKenzie Bay fauna of the lower Yakoun Formation (Queen Charlotte Islands) and the Fitz Creek Siltstone (southern Alaska), the Snowshoe Formation in the Emigrant Creek and Seneca areas yields species of *Otoites* and *Pelekodites* which suggest a pre-Humphriesianum Zone age. At other localities *Megasphaeroceras, Leptosphinctes* and *Prorsisphinctes* indicate the presence of strata which belong to the Subfurcatum Zone (Imlay, 1973, p. 29).

The virtual absence in Oregon of the usually rich faunas of *Stephanoceras, Chondroceras* and *Teloceras* occurring in the Humphriesianum Zone of Alberta and British Columbia is noteworthy. *Stemmatoceras* aff. *S. albertense* McLearn (Imlay, 1973, pp. 89, 90; Pl. 46, figs. 1-9) is very similar to *S. itinsae* in whorl shape, ornamentation and suture pattern but has more closely spaced primary ribs and fewer secondaries per primary. Imlay mentions resemblances of this material with a specimen described by Frebold (1957; Pl. 21, fig. 2a, b; Pl. 23, figs. 1b, c) as

Stemmatoceras albertense McLearn from Ribbon Creek; this specimen is herein referred to *S. itinsae* (McLearn) ♀ (pp. 126-7). The Oregon specimens, however, all come from a conglomeratic sandstone (Lupher's loc. 8) containing fossils which have been derived from underlying parts of the Snowshoe Formation (Imlay, 1973, pp. 29, 30), so have no biostratigraphic significance. Fragments representing four unnamed species of *Stephanoceras* are known from localities within the undifferentiated Snowshoe Formation of the Seneca area. Of these, *Stephanoceras* sp. C and *Stephanoceras* sp. D are associated with *Spiroceras* suggesting a Late Bajocian age and *Stephanoceras* sp. B is an evolute, finely ribbed form associated with a fauna (Lupher's loc. 57) indicative of the Sauzei Zone.

4.6 WYOMING, IDAHO AND UTAH

4.6.1 Previous Work

Thick sequences of grey, shaly limestones with minor sandstone, red beds and massive limestone found along the Wyoming-Idaho border and in north-central Utah have been designated the Twin Creek Limestone. The original definition and subsequent use of this stratigraphic unit have been reviewed by Imlay (1967, p. 2; Table 1) who distinguished seven Members and described their ammonite and bivalve faunas.

4.6.2 Stratigraphy and Faunas

The lowest unit of the Twin Creek Limestone, called the Gypsum Spring Member, varies from 4-120 m in thickness and consists mainly of soft, brownish red to yellow siltstones and claystones which are poorly exposed, with interbedded brecciated and chert-bearing limestones (Imlay, 1967, p. 17). Thick masses of gypsum also occur in some areas. A Lower Bajocian age (Humphriesianum Zone) was suggested for this Member because of its position underlying the Sliderock Member which contains ammonites of earliest Late Bajocian age (Imlay, 1967, p. 19). The Gypsum Spring Member itself is poorly fossiliferous, yielding only fragments of the bivalve *Camptonectes* and some indeterminate crinoid and echinoid remains.

Abruptly overlying the Gypsum Spring Member is the basal oolitic limestone of the Sliderock Member. This unit varies in thickness from 6-86 m, most of its upper parts consisting of dark, fossiliferous, bedded limestones. The ammonite fauna is of interest because at numerous localities the Member contains in its upper parts an association of ammonites which has been compared with species known from the Humphriesianum Zone of western Canada together with *Megasphaeroceras rotundum* Imlay and *Eocephalites primus* Imlay (Imlay, 1967, Table 3). The former species is well known in southern Alaska (Imlay, 1961, pp. 470, 471; 1962, pp. A9-11) where it is associated with "*Dettermanites*" [= *Normannites*] *vigorosus* Imlay, *Leptosphinctes cliffensis* Imlay, *L. (Prorsisphinctes) delicatus* Imlay and *Spiroceras*? in the Twist Creek Siltstone of the Tuxedni Group (Imlay, 1964, Fig. 5). This fauna is correlated with the European Subfurcatum Zone of Late Bajocian age. A single specimen described as *Stephanoceras* cf. *S. skidegatense* (Whiteaves) from 33 m below the top of the Sliderock Member (Imlay, 1967, p. 89; Pl. 6, fig. 10) differs markedly from that Queen Charlotte Islands species in both strength and density of the body chamber ornamentation and should instead be identified with *S. itinsae* (McLearn) ♀. The specimen in question has fine, dense secondary ribbing (with three to each primary), very faint primary ribs and weak tubercles, all characteristic of the body chamber of *S. itinsae* ♀ rather than *S. skidegatense* ♀. The latter has strong secondary ribs with only two to each primary. Imlay (1967, p. 89) noted similarity of this specimen to one from the Fernie Group in Alberta illustrated by Frebold (1957; Pl. 21, fig. 1) which now also is assigned to *S. itinsae* ♀ rather than *S. skidegatense* ♀ (p. 127). This occurrence is presumably stratigraphically lower than the numerous fragments of *Stemmatoceras* aff. *S. albertense* McLearn found with *Stemmatoceras arcicostum* Imlay and the *Megasphaeroceras* faunule in the upper 15 m of the Sliderock Member. Also associated with this fauna are four corroded specimens tentatively identified as *Normannites*? cf. *N. crickmayi* (McLearn) (Imlay, 1967; Pl. 12, figs.3, 4). These specimens have much coarser ribbing than is known on "*N. crickmayi*" [= *Zemistephanus* ♂] and only two secondaries per primary on the phragmocone whorls compared with 3-4 on *Zemistephanus* ♂. Correlation of this fauna in the upper Sliderock Member with the Subfurcatum Zone makes these specimens much younger than any known *Zemistephanus*.

4.7 ARGENTINA AND CHILE

4.7.1 Previous Work

Detailed ammonite zonations and some descriptions of the faunas from the Bajocian of the Cordilleran regions of Chile and central Argentina have recently been presented by Hillebrandt (1970, 1971), Westermann (1971) and Westermann and Riccardi (1972a, 1972b). These zones and their faunas are shown in Table 2. Some stephanoceratid elements of these faunas, collected by G. Westermann, are figured and described herein.

4.7.2 Stratigraphy and Faunas

In Neuquén and Mendoza Provinces (Argentina) relatively thick sequences of shales and marls, with some sandstone interbeds and minor limestones and conglomerates, have yielded ammonite faunas from Lower Toarcian to Oxfordian in age (Westermann and Riccardi, 1972a). The measured sections exhibit many breaks in the record indicated by missing faunal zones; faunas from parts of the "Sowerbyi" and Sauzei Zones are well represented. Faunas representing the Sauzei Zone typically include species of *Emileia, Otoites, Sonninia, Papilliceras* and *Dorsetensia* along with early forms of *Stephanoceras* s. l. (*S. nodosum, S.* (*Skirroceras*) *macrum*) and *Chondroceras* ("*C.*"*giebeli, C. defontii* and *C.* cf. *allani*) (Westermann and Riccardi, 1972a). Faunas of the Humphriesianum Zone seem to be missing; the Subfurcatum Zone is represented by faunas containing *Stephanoceras, Chondroceras* and "*Itinsaites*" associated with *Cadomites* cf. *cosmopoliticum, Teloceras multinodum*, ?leptosphinctids and ?perisphinctids (Westermann and Riccardi, 1972a).

Calcareous shales, marls, limestones and iron oolites in the Chilean Cordillera contain ammonite faunas from the "Sowerbyi" Zone to the Subfurcatum Zone (Hillebrandt, 1970). Several faunas from the Sauzei

Zone have been reported at Espinazito Pass and Manflas. They are characterised by *Emileia, Otoites, Sonninia* and *Papilliceras*. *Chondroceras* aff. *defontii* is also associated with some of these genera (Westermann and Riccardi, 1972a, p. 20). Occurrences of "*Stephanoceras humphriesianum*", *S.* cf. *nodosum, S.* (*Epalxites*) *anceps, Dorsetensia* spp. and *Chondroceras* spp. represent the lower part of the Humphriesianum Zone at Manflas and Salar de Pedernales (Westermann and Riccardi, 1972a, 1972b; Hillebrandt, 1970).

A fauna from Manflas with *Cadomites psilacanthus* and *Stephanoceras triplex* represents the upper part (Blagdeni subzone) of the Humphriesianum Zone.

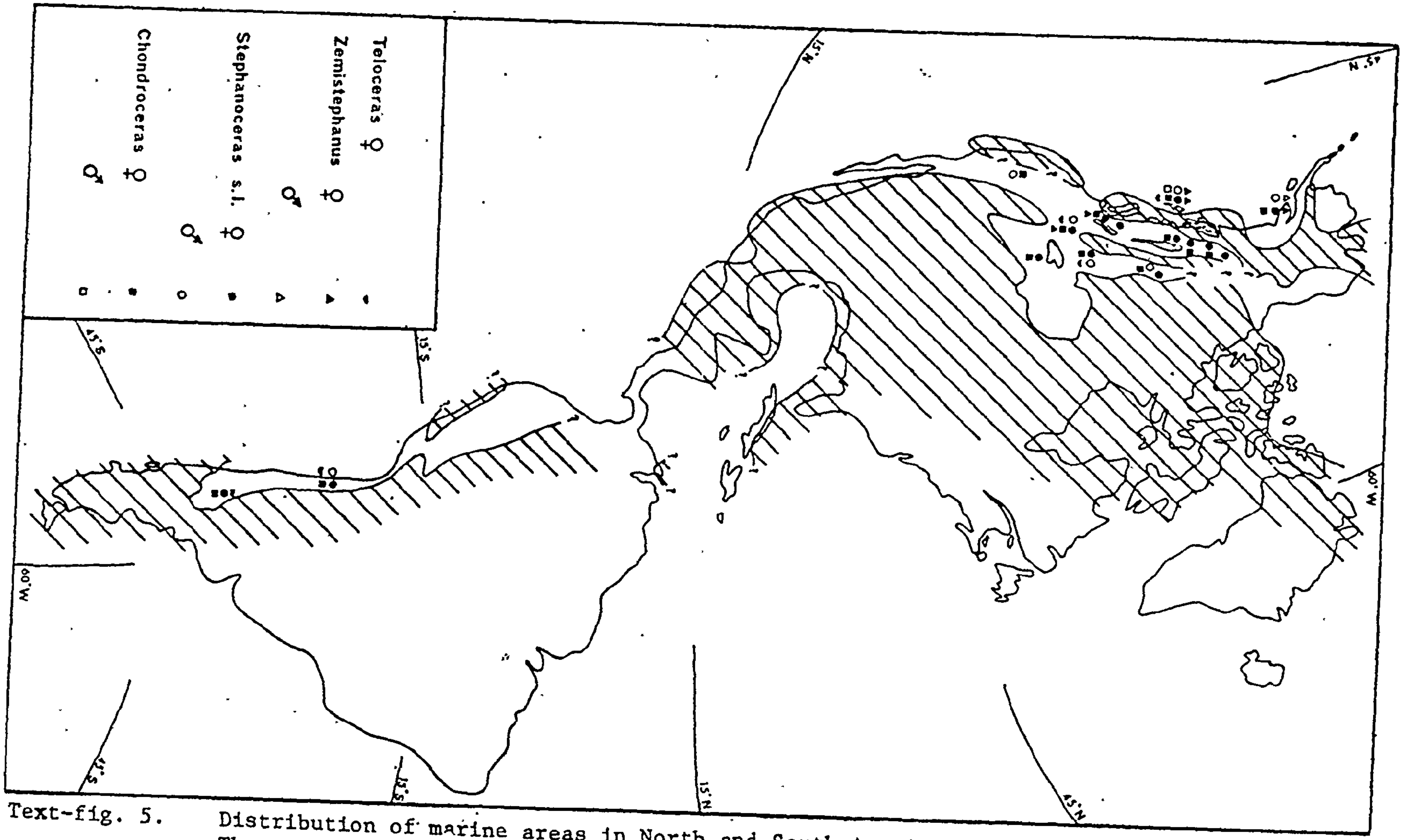
** A new occurrence of *Arkelloceras* cf. *A. tozeri* in northern Alaska has come to my attention since this chapter was written (Imlay, 1976). This new material comes from the Kingak Shale on the Canning River where it occurs above *Pseudolioceras*, again suggesting a Lower Bajocian age.

CHAPTER 5

PALEOGEOGRAPHY

Attempts to reconstruct the paleogeography of the eastern Pacific margin during Middle Jurassic time, dependent as they are on published information on lithologies and faunas, vary in accuracy and detail throughout the area under consideration. In such well-studied regions as Alaska, where good stratigraphic and paleontologic control has been established, much more detailed schemes have been proposed (Imlay and Detterman, 1973). Text-fig. 5 shows the general distribution of marine areas for Middle Jurassic time; known occurrences of some significant ammonite genera from the Sauzei and Humphriesianum Zones (Lower Bajocian as used here) are indicated.

A widespread marine transgression, beginning in the Aalenian (Westermann, 1964c), attained maximum extent during the Bajocian when it covered extensive areas along the southern and southwestern coastlines of Alaska and limited areas in the north. Accumulations of thick sequences of coarse and medium-grainsize graywackes, polymictic conglomerates, siltstones and shales showing great lateral variations in thickness and the presence of regional unconformities suggest rapid erosion of rising borderlands into shifting and subsiding basins along the southern coast (Imlay and Detterman, 1973). These sediments comprise the Red Glacier Formation, Gaikema Sandstone, Fitz Creek Siltstone and Cynthia Falls



Text-fig. 5. Distribution of marine areas in North and South America during the Middle Jurassic. The occurrences of selected ammonite genera from the Sauzei and Humphriesianum Zones (Lower Bajocian) are shown. Diagonal lines represent land areas.

Sandstone. The presence of stephanoceratid ammonites in the southern Yukon (Frebold and Tipper, 1970, p. 10) suggested to Imlay and Detterman (1973, p. 17) the possibility of a marine connection during Lower Bajocian time between southeastern Alaska and that area. However, these could have migrated north from the Alberta Basin where they were common. Elsewhere in northern Alaska and in the Canadian Arctic islands faunas representing the Humphriesianum Zone are missing (Frebold, 1961, pp. 25, 32; Imlay and Detterman, 1973, p. 16), although these are common in Western Europe and western North America. The Aalenian *Erycitoides howelli* - *Pseudolioceras mclintocki whiteavesi* faunule also occurs in southern Alaska, northeast Yukon and the Canadian Arctic (Westermann, 1964c, p. 345; Frebold, 1961, pp. 25, 26).

In northern Alaska, Aalenian siltstones and shales with ironstone concretions and some graywackes of volcanic derivation are unconformably overlain by Bathonian rocks (Imlay and Detterman, 1973). The Colville Trough of the northern Yukon represents a southward embayment of the Arctic Ocean in which black shales and sandstones were deposited throughout the Jurassic; it was believed that this trough was closed to the south. However, in several areas of north and central Yukon which were previously believed to have been land surfaces during the Jurassic, strata bearing Lower, Middle and Upper Jurassic ammonites have recently been reported (Frebold et al, 1967; Jeletzky, 1975). The Kingak Shale (Lower and Middle Jurassic), consisting of neritic and upper bathyal marine shales was deposited further south in the intra-cratonic

Porcupine Plain-Richardson Mountain Trough which, according to Jeletzky (1975) was a persistent feature throughout Jurassic and into mid-Lower Cretaceous times, extending into east-central Alaska and opening southward into the Mesozoic orogenic belt of the Canadian Cordillera.

During the Middle Jurassic, rapidly subsiding, elongated troughs of the Insular and Intermontane Belts of British Columbia were bordered by emergent land masses (Douglas et al, 1970, Fig. VIII-1). These features are interpreted as successor basins and foredeeps, formed over an eastward dipping subduction zone, which were filled with volcanic rocks and volcaniclastic sediments derived from nearby arc systems (Monger et al, 1972). Uplift of the emergent areas occurred during the Inklinian Orogeny (latest Triassic and early Jurassic) accompanied by emplacement of granitic plutons and metamorphism. Erosion of these rising geanticlines produced sediment which was deposited in neighbouring basins to form coarse clastic wedges characterised by a lack of lateral continuity, frequent unconformities and rapid facies changes. Middle Jurassic strata throughout the Cordilleran Orogeny are mainly of volcanic origin: coarse volcanic agglomerates, tuffs, flows of andesite and basalt, with interbedded sequences of reworked, water-lain tuffs, graywackes, siltstones, shales and argillites. In the south the Insular Trough is marked by over 2,000 m of Lower Jurassic porphyritic andesites (Bonanza Formation) on Vancouver Island while, at the same time in the north, limestones and shales were deposited under more stable conditions. In the Middle Jurassic this northern area became more unstable with accumulation of thick, porphyritic andesitic agglomerates, tuffs, reworked volcanic sandstones and siltstones in a shallow sea adjacent to an area of active volcanism close to the east coast of the Queen Charlotte Islands (Sutherland Brown, 1968). Plant fossils and carbonized wood are commonly associated with abundant marine molluscan faunas in the lower Yakoun Formation.

In the northern mainland of British Columbia volcanic debris is again the major component in conglomerates, graywackes and argillites making up the Lower and Middle Jurassic Laberge Group (3,500 m) in the Whitehorse Trough (Wheeler, 1961). This material was derived from the rising Coast Geanticline to the west and southwest and from the Omineca Geanticline to the east. During the Middle and Upper Jurassic the rate of sedimentation declined with arenites, shales and some coal deposits accumulating along the western margin of this trough, indicating decreasing relief of the land area to the west.

Rocks of Lower and Middle Jurassic age make up the Hazelton Group which is widespread throughout central and west-central British Columbia (Tipper, 1959; Duffell, 1959). This thick sequence of graywackes with some interbedded cherts and argillites, volcanic tuffs and breccias was deposited in the Nechako Trough. It is everywhere dominated by pyroclastic agglomerates and tuffs of andesitic and basaltic composition, with fossiliferous marine sediments consisting of reworked volcanic detritus (Lord, 1948; Baer, 1967).

Another thick, marine turbidite sequence forms the eastern limb of a synclinorial structure in southwestern British Columbia at Manning Park (Coates, 1967; Frebold et al, 1969). Breccias, conglomerates and medium-grainsize clastics containing fragments of andesitic and dacitic volcanic origin are common, with lesser amounts of shale and argillite. There is evidence of some deposition by turbidity currents and rapid lateral facies changes indicate an unstable environment. Bajocian ammonites from several successive Zones are found in this sequence; impressions of driftwood and logs indicate the presence of land nearby. On the western limb of this structure most of the equivalent rocks are fine, marine clastics with some sandstones of dacitic origin, massive lavas and pyroclastics. Again there is evidence of turbidite deposition.

The Jurassic Fernie Group of the Canadian Rocky Mountains and Foothills is a relatively thin sequence (maximum 400-500 m) with many periods of non-deposition indicated by the fossil zonation (Frebold, 1957, p. 2). Accumulation was slow, in a shallow sea with periodic regressions. While the Middle Jurassic deposits only reach a maximum thickness of about 100 m, the Lower Bajocian transgression was one of the most extensive and strata bearing the so-called "*Teloceras*-fauna" (Sauzei and Humphriesianum Zones as suggested by Westermann, 1964b) are widespread and called the Rock Creek Member. This unit usually consists of dark grey shales with harder bands of dark, calcareous sandstone. However, in the north-eastern part of the basin a very shallow, near-shore facies is indicated by sandstones with ripple marks, tracks and plant remains (Frebold, 1957, pp. 15, 16). The sequence of minor epeirogenic movements and thin deposits of shallow-water sediments interbedded with sandstone derived from the continent to the east (Sweetgrass Arch), all point to a stable environment.

During Middle Jurassic time the seas of the Alberta Trough advanced southward into the shallow Williston Basin, reaching southern Saskatchewan, southwestern Manitoba and the western Dakotas. From the eastern margins of this Basin, relatively thin (200 m) Middle Jurassic evaporites, quartzose nearshore marine sands and basinal clays grade southwestward into thicker (1,000 m) evaporites, claystones, limestones and redbeds marking the centre of the basin in southwestern Wyoming (Carlson, 1968). The upper Lower Bajocian (Humphriesianum Zone) is probably represented by the Gypsum Spring Member of the Twin Creek Limestone which crops out along the Wyoming-Idaho border and south into Utah (Imlay, 1967). This unit is predominantly brownish-red to yellow siltstones and claystones with interbeds of limestone, often brecciated and chert-bearing, and local developments of gypsum. Although of very uneven thickness, it generally thickens toward the west and southwest. Fossils are scarce throughout consisting mainly of crinoid columnals and echinoid spines with a few bivalves. On lithologic and stratigraphic grounds the Gypsum Spring Member is tentatively correlated with the lower part of the Gypsum Spring Formation of north-central Wyoming, the lower redbed member of the Piper Formation in southern Montana and parts of the middle shale member of the Sawtooth Formation of north-west Montana

(Imlay, 1967, pp. 19, 20). The Gypsum Spring Member indicates accumulation of fine sediments in a very shallow sea which was advancing eastward from the deeper western part of the basin. The extent of redbeds and gypsum deposits of the same age to the east, westward thickening of units and more abundant fossils to the west all suggest that the source of the clastic sediment was south and west of the basin (Imlay, 1967, p. 22).

Rocks deposited in eastern Oregon during Bajocian time consist of marine volcaniclastic sediments, lavas and volcanic breccias interbedded with limestones, mudstones and claystones. This thick sequence (400-900 m) exhibits marked lateral facies changes and most units are recognised as local members; correlation of these members is achieved using ammonite faunas (Imlay, 1973, pp. 8-11).

Throughout the Mesozoic those parts of the South American continent now occupied by the Andean Cordillera and the narrow west coast were the site of several elongated, meridional marine basins. The unstable nature of this area during the Jurassic is reflected in alternating marine transgressions and regressions producing accumulations of marine clastics and continental redbeds, both of which were associated with volcanic activity (Harrington, 1961, p. 175; 1962, pp. 1794-5; Childs and Beebe, 1963). However, the Bajocian was apparently a time of stability during which shelf sediments (sandstones, limestones, marls and oolites) and deeper-water shales were deposited, with only localised volcanic activity.

The Peruvian and Chile-Argentine Basins are characterised by marine transgression in the Aalenian-Bajocian. In particular, sequences containing Lower Bajocian faunas of the "Sowerbyi" and Sauzei Zones are abundant in Argentina and northern Chile (Westermann, 1967; Stipanicic, 1969; Hillebrandt, 1970; Westermann and Riccardi, 1972a, 1972b). Interbedded sandstones, shales with concretions, marls, limestones and conglomerates were deposited during this time in the Neuquén-Mendoza embayment (Groeber et al, 1953, fig. 18; Westermann and Riccardi, 1972a). Bajocian sediments at Caracoles and Pedernales in northern Chile are associated with andesitic volcanics. The Lower Bajocian Torcazas and Coronado Formations at Caracoles, predominantly brown and grey calcareous sandstones with interbedded sandy shales and some fine-grained conglomerates contain abundant fossil molluscs (Harrington, 1961, p. 187). At Manflas, thick shales and marls containing ammonites belonging to the Sauzei Zone are overlain by iron oolites with stephanoceratids indicative of the Humphriesianum Zone. Other faunas representing the Humphriesianum Zone are known from Salar de Pedernales, the lower part of the sequence at Quebrada Asientos and the Coastal Cordillera near Santiago, all in northern Chile (Hillebrandt, 1970; Westermann and Riccardi, 1972b). However, in Argentina only two records of Humphriesianum Zone faunas are known (Stipanicic, 1969, p. 374), but these need verification.

Close generic, and sometimes specific, relationship between Bajocian ammonites from the eastern Pacific margins of both North and South America with those of Northwestern Europe suggest a direct migration route between these two areas via an early Atlantic (Westermann, 1969; Khudoley, 1974). Westermann has also indicated the probability of migration by longer routes along the continental shelves. Occurrences of elements from the *Erycitoides howelli* fauna (Late Aalenian, Howelli Zone) in southern Alaska, northeast Yukon (Westermann, 1964b, p. 338) and the Canadian Arctic (Frebold, 1961) indicate one such route through the Arctic. However, during much of the Lower Bajocian this route must have been closed, there being no record in the Canadian Arctic of the stephanoceratid faunas typical of this time (Frebold, 1961, pp. 25, 32).

Indeed, recent investigators now propose that the initial rifting and opening of the central Atlantic occurred 180-200 million years ago (Late Triassic and Early Jurassic) based on distribution of basaltic lavas and intrusives, the magnetic "quiet zones", backward extrapolation of seafloor spreading rates and paleomagnetic studies (Larson and Pitman, 1972; Phillips and Forsyth, 1972; Pitman and Talwani, 1972; Dalrymple et al, 1975; Gibb and Kanaris-Sotiriou, 1976).

Jurassic marine sediments are known from the Labrador Sea and Labrador coast (McMillan, 1973; Johnson et al, 1974; King and McMillan, 1975), east Greenland and east-central Mexico (Hallam, 1971a) and western Cuba (Meyerhoff et al, 1969). At a sub-bottom depth of 1412 m on the floor of the Blake-Bahama Basin (Leg 44, Site 391) "hard, red marly limestone of Upper Jurassic (Tithonian-Kimmeridgian) age" was encountered some 300 m above probable basement when the drill-hole was abandoned

(Scientific Staff, 1976). At least 1,100 m of Upper Jurassic and Lower Cretaceous clayey limestones have been recorded and Tithonian (Upper Jurassic) ammonites are common in the lower parts. Nearby (Leg 11, Site 100), green-grey limestones of possible Callovian age (uppermost Middle Jurassic) contain a microfauna suggesting a neritic to upper bathyal environment of deposition (Scientific Staff, 1970).

CHAPTER 6

FAUNAL REALMS IN THE JURASSIC

Increasing knowledge of Jurassic ammonoid faunas has necessitated constant revision of the concept of faunal realms first discussed by Neumayr (1883) and further developed by Uhlig (1911). As pointed out by Arkell (1956) these early schemes attempted to deal with the whole of Jurassic time, leading to many discrepancies as new faunas became known. Such comprehensive treatment was impossible because, as is now clear, the differentiation of Jurassic ammonoid faunas was both spasmodic and progressive, reaching a maximum in the Upper Jurassic (Gordon, 1976). Arkell still believed that the Lower Jurassic ammonoid faunas were universal in their distribution (Arkell, 1956, p. 609) but more recent work has shown the existence of provinciality throughout most of the Lower Jurassic (Dean et al, 1961; Hallam, 1971b; Sapunov, 1967; Howarth, 1973).

Arkell (1956) recognised three Jurassic ammonoid Faunal Realms, the Boreal, Tethyan and Pacific, distinguished mainly on the basis of restricted occurrences of certain ammonite families. The Boreal and Tethyan Realms are clearly discerned on this basis for most of the Jurassic, though the boundary between them frequently fluctuated north and south. The causes of initiation, maintenance and periodic expansions of these two Realms have been the subject of much recent discussion

(Imlay, 1965; Stevens, 1971; Stevens and Clayton, 1971; Hallam, 1969, 1971b).

Development of the Pacific Realm, beginning in the Lower Bajocian with the appearance of the "peculiar Pacific genera *Pseudotoites* and *Zemistephanus*" was proposed by Arkell (1956, p. 609). These genera were supposedly restricted to Western Australia, Indonesia and the western seas of North and South America. Records of *Zemistephanus* from Western Australia are now believed due to misidentification (p. 81) and it seems this genus was endemic to the North American Cordilleran geosyncline. It is definitely known only from the Queen Charlotte Islands and southern Alaska, where it occurs in the uppermost Sauzei or lower Humphriesianum Zones. *Pseudotoites* is well known from the Sowerbyi Zone of southern Alaska (Westermann, 1969), Chile and west-central Argentina (Westermann and Riccardi, 1972a). The transfer of *Zemistephanus carlottensis* (Whiteaves) to *Pseudotoites* by Arkell (1954) has been shown to be unwarranted (Imlay, 1964; Westermann, 1964a). *Pseudotoites* is also known from Western Australia (Arkell, 1954) and some islands of the Indonesian Archipelago (Westermann and Getty, 1970). On the other hand the distribution of the overwhelming number of Lower Bajocian genera is cosmopolitan: *Otoites* (including *Emileia*), *Sonninia* and *Stephanoceras* (*Skirroceras*) in the Sauzei Zone; *Stephanoceras* s. s. (including *Normannites*), *Teloceras* and *Chondroceras* in the Humphriesianum Zone. Other genera do seem to be endemic to the western Cordilleran seas of North America: *Parabigotites* ♀ & ♂; *Zemistephanus* ♀ & ♂.

The restricted occurrence of these few genera in faunas otherwise composed of predominantly cosmopolitan families indicates some endemism but does not justify separate Realm status.

Also, *Pseudotoites* and *Zemistephanus* are of different age, further diminishing the number of supposedly "unique" forms defining the Pacific Realm at any one time. Different parts of the proposed Pacific Realm were inhabited at various times by ammonite genera which migrated from the Boreal, eastern Tethyan and western Tethyan Realms. While it is clear that some genera were able to migrate across the Pacific basin, others remained of quite restricted distribution (Westermann, 1969; Khudoley, 1974).

Of greater significance may be the geographic distribution of *Arkelloceras* which is known in relative abundance from strata of uncertain age in the North West Territory and Arctic areas of Canada (Frebold, 1961; Frebold et al, 1967) and represented elsewhere in the Sauzei Zone by single specimens from southern Alaska (Imlay, 1964) and western Alberta (Westermann, 1964c)*. The dominance of this genus in Arctic areas may represent the initiation of the more strongly defined Boreal faunas with *Cranocephalites* in the Upper Bajocian and Lower Bathonian (Frebold, 1961, p. 36).

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* see note, p. 52.

CHAPTER 7

SEXUAL DIMORPHISM AND TAXONOMY

7.1 The Nature of Dimorphism in Ammonoidea

Early authors frequently recorded the occurrence in the same beds of two groups of ammonites having similar morphology but differing markedly in size; the varied interpretations given to this phenomenon have been extensively reviewed by Makowski (1962) and Callomon (1963). These two writers also presented detailed studies comparing the morphology of many such paired groups of Jurassic ammonites and their suggestion that these groups probably represent sexual dimorphs has prompted much recent investigation. Sexual dimorphism is now recognised as a commonplace feature of ammonoids throughout most of the Jurassic Period (Westermann, 1964a; Howarth and Donovan, 1964; Lehmann, 1966; Palframan, 1966, 1967, 1969; Cope, 1967; Guex, 1968; Zeiss, 1969; Tintant, 1969; Westermann and Riccardi, 1972a; Verma and Westermann, 1973) with rarer occurrences also in Cretaceous (Cobban, 1969; Kennedy, 1971; Reyment, 1971) and Paleozoic forms (Davis, Furnish and Glenister, 1969).

One of the most conspicuous features of dimorphism in ammonites is difference in size of the mature shell; many early workers interpreted the smaller members of a dimorphic pair (microconchs) as immature or dwarfed representatives of the larger form (macroconchs). Thus it became important to be able to recognise shell features indicating attainment of the adult stage with consequent cessation of growth. The following phenomena are now generally accepted as characteristic of the adult shell:

1. Approximation of the last few septa (shortening of the camerae) as growth decelerates approaching adulthood. The associated sutures are usually simplified.

2. Change in density and/or pattern of shell ornamentation is usually closely associated with the adapical end of the body chamber.

3. Departure of the body chamber whorl from the growth spiral followed throughout the phragmocone, usually seen as egression of the umbilical seam.

4. Modification at the aperture such as constrictions, flares, lappets, rostra and horns.

It is now recognised that the smaller microconch members of proposed dimorphic pairs are indeed adult shells rather than juveniles and while they differ more or less strongly from the macroconch in size and appearance at the adult stage, their inner whorls are indistinguishable. The identical morphology of early growth stages and the fact that parallel modifications occur at similar growth stages in both forms suggest close genetic relationship. Callomon (1963, p. 28) has also indicated that new features appear more or less simultaneously in both evolving "lineages" during phylogeny.

Makowski (1962, p. 13) advanced four pre-requisites for acceptance of the theory of sexual dimorphism in ammonites which, with some modifications, have been followed by later workers:

1. "identical initial stages of ontogeny in both (small and large) forms and identity of their phylogeny." As mentioned above, this feature has been the essential basis for pairing supposed dimorphs. The assumption that such morphological similarity derives from close genetic relationship is supported by the occurrence of parallel morphological changes at comparable stages in both "lineages" during ontogeny (p. 98) and phylogeny (Callomon, 1963, pp. 35, 36). It is noteworthy that phylogenetic changes are not always simultaneous in both "lineages" as seen in Middle Jurassic Kosmoceratidae (Callomon, 1963, pp. 36, 37). Rib densities on the phragmocones of supposed dimorphs are not always identical (Cope, 1967).

   A quite different expression of dimorphism has been suggested by Reyment (1971) in several species of Cretaceous *Benueites* where the nature and density of ribbing and nodes on the supposed dimorphs are consistently different while adult diameters are the same.

2. "lack of intermediate forms in adult (gerontic) stages." In most reported cases of ammonoid dimorphism there is a clear separation of adult specimens into two groups with different maximum size and number or whorls. In those living cephalopods which are markedly dimorphic the male dimorph is consistently smaller (Westermann, 1969a, p. 19)

and it is on this basis that the sex of fossil macroconch/microconch forms is assigned. Some fossil dimorphic faunas, however, are not clearly separable into large and small forms, there being an overlap in the range of adult shell sizes (Cobban, 1969; Reyment, 1971).

3. "presence of both forms in the same strata." Makowski himself (1962, p. 13) noted the difficulty of fulfilling such a condition due to:

   a. uncertainty in defining the "same strata" where individual beds vary in thickness. While study of a large, essentially contemporaneous, population from a single horizon is ideal (e.g. those described by Lehmann, 1966; Palframan, 1966, 1967, 1969), many dimorphs must be recognised from scattered collections through perhaps tens of metres of section.

   b. uncertainty in determining the stratigraphic range of a species, especially as specimens become increasingly rare towards the top of its range.

   While there are conditions which may lead to segregation of dimorphs (see 4,. below), the occurrence of both forms in the same beds with at least a closely similar stratigraphic range is still strong evidence in establishing dimorphic relationship.

4. "numerical ratio of the two supposed sexes (sex ratio), comparable to that observed in living forms." In many reported dimorphic faunas

the macroconch/microconch ratio departs significantly from unity, though the expectation that such a ratio properly reflects conditions in the living population has been expressed (Makowski, 1962, pp. 13, 14; Howarth and Donovan, 1964, p. 292). Westermann (1964a, pp. 36, 37) has outlined some of the factors which may modify numerical correspondence of dimorphs in living and fossil populations. Some of these reflect behaviour of the living population while others are related to post-mortem behaviour of the shell or biases introduced during fossilisation and collecting.

Sexes in some living cephalopods undergo temporary separation during migrations associated with breeding (Westermann, 1969a, p. 20). Dimorphs varying strongly in size and ornamentation may have been adapted to different ecological niches and so spent even longer periods of their life cycles in separate schools. Mortality rates in the two sexes may also have been different (Makowski, 1962, p. 14). Factors associated with different behaviour of the shell immediately after death of the animal and during fossilisation which may alter the sex ratio include:

a. different rates of post-mortem decay or removal of the animal from the body chamber to permit floating/sinking of the shell (Westermann, 1964a, p. 37);
b. preferential destruction of larger shells during burial (Makowski, 1962, p. 14);
c. restriction of mineral replacement to parts of the shell below a

certain maximum size (Palframan, 1966, pp. 290, 301, 302);

d. collection failure, particularly in older collections where microconchs were often regarded merely as immatures.

In the faunas described from the Queen Charlotte Islands several instances of sexual dimorphism are recognised based on the pre-requisites outlined above. Two forms of dimorphism occur: one in which the adult forms differ in size and apertural modification (Family Stephanoceratidae; and corresponding to Type II dimorphism as suggested by Houša, 1965, p. 33) and another in which adult size is the only difference (Family Sphaeroceratidae; Type I dimorphism of Houša). It should be emphasised that while dimorphism so far seems restricted to these two types, attempts to reconstruct ammonite classification and phylogeny on this feature alone are premature (Makowski, 1962; Houša, 1965; Morton, 1971), especially in light of the fact that most Triassic and Cretaceous ammonites do not exhibit shell dimorphism.

Comparison of the phragmocone whorls in forms which, in this thesis, are considered to be sexual dimorphs is based on the dimensions and cross-sectional shape of the whorls, density and pattern of the ribs, nature of the tubercles, suture patterns and ontogenetic development. These are illustrated and discussed under the appropriate species descriptions in Chapter 8. In each case of dimorphism recorded here, specimens came from beds at a single locality in the lower part of the Yakoun Formation; macroconchs always outnumbered microconchs by at least 2:1.

7.2 Taxonomy of Dimorphs

Taxonomic treatment of recognised dimorphic pairs remains in dispute. Some authors conclude that, since they represent the two sexes of a single biospecies, or at least closely approach that ideal within the limits set by the necessarily morphologic nature of all paleontologic "species", they should bear the same genus-level and, where recognisable, specific names (Makowski, 1962; Lehmann, 1966; Palframan, 1966, 1967, 1969; Cope, 1967; Guex, 1967; Westermann, 1969b). Others, emphasising the impossibility of defining true biospecies in fossil faunas and the nature of morphospecies to which paleontologists will always be restricted, propose classification of dimorphs as separate subgenera (Callomon, 1963, 1969).

Difficulties facing the paleontologist in properly recognising biospecies as opposed to morphospecies seem to me not to mitigate against recognition of a dimorphic pair by using the same biological name. The additional complexity mentioned by Callomon (1969, p. 118) of having to delineate fossil species in a "vertical" as well as "horizontal" sense is equally a problem whether dealing with supposed biospecies or morphospecies. Tracing phylogenetic changes in both "lineages" of a dimorphic pair through successive Zones, as has been excellently portrayed by Callomon (1963, pp. 35, 36; Pl. I, figs. I-Q) for the Family Kosmoceratidae, confirms that we are dealing with an evolving population closely approximating a biospecies. Continuing research on other groups in favourable sequences should increase our understanding of ammonite phylogeny and taxonomy; increasing recognition of the behaviour of dimorphic pairs in space and time must also increase our feeling for ammonites as dynamic populations.

Taxonomic treatment of dimorphs has sometimes depended on the degree of differentiation between the two sexes. Thus in groups exhibiting Houša's Type I dimorphism (adults differing mainly in maximum size), dimorphs were usually separated only at the species or subspecies level (*Chondroceras, Scaphites*). Those forms which differed in size, ornamentation of the body chamber and modification of the aperture (Houša's Type II dimorphism) were usually separated into different subgenera, genera or even families (*Stephanoceras* and *Normannites; Emileia* and *Otoites*). Still others differ in adult size and ornamentation but have similar apertures (Macrocephalitidae) and have been treated as separate subgenera (Callomon, 1955, p. 237).

Each of the three Lower Bajocian faunas described from the Yakoun Formation on the Queen Charlotte Islands is of very low diversity, usually with only one stephanoceratid and one sphaeroceratid dimorphic species at each locality (Table 5). Thus difficulties due to possible overlap of morphological features between closely related species are minimised, especially amongst the less-variable microconchs, allowing dimorphs to be paired at the species level. Corresponding dimorphs are regarded as the sexes of a single ammonite species and given the same name; the probable sex of each dimorph is indicated by the use of the appropriate biological symbols, though this is recognised as being a convention (Palframan, 1969, p. 148). In this usage I am following the procedures proposed by Palframan (1969), Westermann (1969b), Makowski (1962) and Guex (1967), among others. Where one partner of a dimorphic pair has not been previously named no new name is given and the two dimorphs are regarded as being conspecific. In those cases where both dimorphs have previously been described and named, rules of priority must be followed when choosing a single name for the species.

While each dimorphic species must be treated as a separate case depending on the previous taxonomic designations of each member, there are some general rules which should be observed to avoid confusion:

1. When two previously-named species are drawn into synonymy as sexual dimorphs the choice of both generic and specific names must be based on priority. This procedure has not always been followed: Guex (1967) placed *Onychoceras* Wunstorf 1907 in synonymy with *Hammatoceras* Hyatt 1867 not on grounds of priority (which, in this case, would have been the correct procedure) but because the former was "a genus whose taxonomic value may be largely doubtful" and whose "existence is not justified" (p. 11).

2. Pairing of two species from different genera does not always mean that the two genera involved can be paired (as is usually done in the subgeneric approach to the taxonomy of dimorphs), even in the case where the type species are paired. For instance, if *Normannites* Munier-Chalmas 1892 is understood to include as synonyms the Canadian forms *Kanastephanus* McLearn 1927 and *Itinsaites* McLearn 1927 (Arkell, 1957, p. 289), then microconch forms of both *Zemistephanus* and *Stephanoceras* are both to be found in *Normannites*. Pairing of these dimorphs on the grounds of priority alone would result in the following:

Stephanoceras Waagen 1869 (macroconch: *Stephanoceras* s. s.)
(microconch: *Normannites* s. s.)
Normannites Munier-Chalmas 1892 (macroconch: *Zemistephanus*)
(microconch: *Normannites*)

In this case the well-established *Normannites* Munier-Chalmas would take on a quite different meaning from that originally proposed, leading to taxonomic confusion; recognition of dimorphs has here produced a more detailed and more truly evolutionary taxonomy, separating microconch forms which had previously been included together in *Normannites* (McLearn, 1949; Arkell, 1957; Imlay, 1964). While examination of more extensive collections has enabled separation of *Kanastephanus* from *Normannites* (p. 86) which avoids the possible confusion caused by pairing of certain genera as outlined above, the choice of *Zemistephanus* McLearn 1927 as the nominate genus rather than *Kanastephanus* McLearn 1927 is an arbitrary one based essentially on the larger size and possible greater interspecific variation of the macroconch form.

This case is instructive in view of the difficulty raised by some of finding equivalent numbers of macroconch/microconch species in two supposedly dimorphic genera (Callomon, 1969, pp. 118, 119; Guex, 1968, pp. 57, 81). Guex (1968) suggested limiting the number of macroconch species to correspond with the number of recognised microconch species, the latter generally being fewer in number because of lower interspecific variation. While such an approach may represent a more pragmatic treatment of the species problem it does not allow for such factors as differential preservation, collecting failure and increasing systematic refinement, and so may be no closer to biological reality.

3. As suggested by Westermann (1969b, p. 235) "genus-group names are synonymized prior to the species epithets" (keeping in mind the restriction mentioned in (1) above). In the case of *Stephanoceras yakounense* McLearn 1930 and its microconch dimorph *Itinsaites itinsae* McLearn 1927 the specific epithet "*itinsae* 1927" has priority; however, if species-name priorities were also used to determine generic placement, the situation could arise in which some dimorphic pairs of the *Stephanoceras - Normannites* [= *Itinsaites*] group would be classified as *Stephanoceras* and others as *Normannites*.

When two previously-named species are drawn together as dimorphs the determination of the correct specific epithet must be based on priority regardless of which generic name has been retained.

4. Full descriptions and synonymies of both dimorphs are given separately, then comparison of their juvenile morphologies is made. The holotype of a dimorphic species must be that of the species having priority irrespective of the generic name retained (some will be macroconchs, others microconchs within the one genus); a specimen representing the other dimorph is designated "allotype".

CHAPTER 8

SYSTEMATIC PALEONTOLOGY

8.1 Abbreviations and Measurements

All measurements of specimens are given in millimetres. Whereever possible whorl dimensions were measured on cut and polished cross-sections or on broken specimens obtained during dissection. Most measurements were made on internal molds. The following abbreviations are used throughout the text and in Text-figures:

D = shell diameter.

W = maximum whorl width measured between ribs or tubercles.

H = height of the whorl measured from the umbilical seam to the venter.

U = diameter of the umbilicus measured between the umbilical seams.

P = primary ribs; the number of ribs per half-whorl always counted adapicad from the stated shell (or umbilical) diameter.

S = secondary ribs on the venter; numbers counted the same way as for primary ribs.

P_L = length of the primary ribs measured from the umbilical seam to the centre of the tubercle or point of furcation.

The graphs represent mass curves with usually more than one measurement taken from each specimen; points measured on phragmocone whorls are represented by open symbols, those from the body chamber are filled in. Macroconchs, microconchs and specimens from different localities are indicated by the use of various symbols which are explained on each graph. Points joined by thin, continuous lines represent measurements made from various growth stages on the same specimen ("individual growth curve"); heavier continuous lines joining numbered points represent measurements from holotypes; other dashed lines joining numbered points represent measurements on "species" considered to be synonymous with the named species. Regression lines, based only on measurements from the phragmocone whorls, are represented by the heaviest continuous lines and, where relevant, the suggested sexes are indicated by the appropriate symbols. Small, inset axes indicate the approximate positions of "growth lines" for each dimorph.

On graphs showing rib counts, individual points from different growth stages of each specimen are joined to produce a "growth cruve", emphasising individual ontogenetic variation. The use of umbilical diameter allows data to be incorporated from the inner whorls of undissected specimens and figured specimens, at least for primary ribbing exposed on the lower flanks or umbilical walls.

The diameter at which individual sutures were drawn is indicated to the right of each figured suture. Shell diameters at which cross-sections were drawn are indicated on each diagram. Sections through body chamber whorls are shaded; black areas represent ribs and tubercles.

8.2 Systematic Descriptions

ORDER AMMONOIDEA
Suborder AMMONITINA Hyatt, 1889
Superfamily STEPHANOCERATACEAE Neumayr, 1875
Family STEPHANOCERATIDAE Neumayr, 1875
Genus *Zemistephanus* McLearn, 1927

Type Species: *Ammonites richardsoni* Whiteaves, 1876 (by original designation).

Discussion: The type species, originally described by Whiteaves (1876, pp. 32, 33; Pl. 5, figs. 1, 2) was based on a single specimen from the collection of fossils made by J. Richardson in 1872 from the shores of Skidegate Channel in the Queen Charlotte Islands. No further information as to its precise locality was given. McLearn (1929, pp. 18-21) described an additional specimen as *Zemistephanus richardsoni* (Whiteaves) and two other specimens (designated *Z. vancouveri* and *Z. funteri*, McLearn, 1929 spp.) from the lower part of the Yakoun Formation on the north-east shore of MacKenzie Bay, Maude Island, Skidegate Channel (Text-fig. 1). More recent collections by Sutherland Brown (1968) and myself have produced a number of macroconch *Zemistephanus* only from this locality, so it would seem certain that this is the locality from which the holotype of *Z. richardsoni* came. *Zemistephanus* appears to be endemic to western North America and is of restricted stratigraphic range and diversity; yet the identity and affinities of the genus have been subject to widely varying treatment by other authors.

Another specimen from Skidegate Channel recently recognised as belonging to this genus (Imlay, 1964) was described by Whiteaves (1876, pp. 38, 39) as *Ammonites carlottensis*. However, this species was not included by McLearn (1927, 1929) in his original discussion of the genus *Zemistephanus* and has been variously placed in *Perisphinctes*, *Stephanoceras* and *Pseudotoites*. Arkell (1954) believed there was a strong resemblance between *A. carlottensis* Whiteaves and the West Australian *Pseudotoites leicha[illegible]ti* (Neumayr) and so transferred the poorly known Canadian species to that genus. Later work on material from southern Alaska, with details of the suture preserved for the first time, resulted in establishing *A. carlottensis* Whiteaves as a *Zemistephanus* (Imlay, 1964). This was based on the strong similarities of the body chamber, ornamentation and suture with *Z. richardsoni* (Whiteaves). Similar characters are used here (p. 111) in transferring the Alaskan material described by Imlay (1964, pp. B50, 51) as *Teloceras itinsae* McLearn to *Zemistephanus* as *Z. alaskensis* n. sp. The aplanulate structure of the septum indicates that *Zemistephanus* should be affiliated with the family Stephanoceratidae rather than the Otoitidae which exhibit an abullate septum (Westermann, 1964a). E/L and I/U_n are much higher than adjacent saddle elements in the suture.

The two additional species erected by McLearn (*Z. vancouveri* and *Z. funteri*) were based on single, incomplete and poorly preserved specimens. The holotype of *Z. funteri* is badly weathered and one side is missing entirely; it is here regarded as a slightly smaller specimen of *Z. richardsoni*. As previously suggested by Imlay (1964, p. B53), the incomplete holotype of *Z. vancouveri* McLearn appears to be identical with the Alaskan specimens of Z. *carlottensis* (Whiteaves).

Two alleged Australian species described by Arkell (1954), Z. *corona* and Z. *armatus*, have been shown to be coronate developments of *Pseudotoites* (Westermann, 1964a, p. 62). From mainland western Canada several specimens have previously been placed in *Zemistephanus*. "Z. *crickmayi*" Frebold (Frebold, 1957, pp. 52, 53) from the Rock Creek Member of the Fernie Group at Ribbon Creek in southern Alberta is clearly a *Teloceras* (pp. 168-9). "*Zemistephanus*" sp. (Frebold and Tipper, 1973, p. 1123), from Tenas Creek in north-central British Columbia, is represented by a poorly preserved outer whorl with ribbing exhibited only on a short part of the whorl. Coiling and cross-section are not able to be determined and the specimen cannot be identified confidently with *Zemistephanus*.

A single impression of a stephanoceratid ammonite from the Lookout Section in Manning Park, southern British Columbia, was identified as Z. *richardsoni* (Whiteaves) by Frebold (1969, pp. 25, 26; Pl. II, fig. 1; Pl. IV, fig. 1). The specimen in question appears to be complete, so is not significantly larger than other described specimens from Alaska and the Queen Charlotte Islands. However, the occurrence of fine riblets or striae in place of relatively coarse secondary ribs on all visible parts of the flanks and venter and the loss of the large, conical nodes on the body chamber are not characteristic of Z. *richardsoni* (Whiteaves). Whether the specimen is correctly identified with *Zemistephanus* is difficult to judge in the absence of information on the whorl shape.

It is suggested here (p. 166) that *"Teloceras" warreni* McLearn may represent a large form of *Zemistephanus*, being characterised by a narrow umbilicus, steep umbilical wall and large nodes situated low on the flanks.

Whiteaves (1876, p. 33) originally commented on the close relationship of his *Ammonites richardsoni* to *A. coronatus* of Bruguière (1789) and *A. Blagdeni* of Sowerby (1818). Since then several authors (Warren, 1947, p. 72; Frebold, 1957, p. 53; Arkell, 1954, p. 579) have expressed doubt as to the genus-level distinction of *Zemistephanus* and *Teloceras*, though McLearn (1929) in his original description of the type species had already noted two important distinctions: the more dorsal position of the tubercles and the change on the body chamber to more serpenticone coiling in *Zemistephanus*. Westermann (1964a, pp. 62, 68) suggested *Zemistephanus* as a possible subgenus of *Teloceras*. In the description of Bajocian collections from southern Alaska, Imlay (1964, p. B52) distinguished the two genera based on characters of the body chamber. *Zemistephanus* is characterised by "rather marked uncoiling of the body chamber, the low position of the tubercles on the flanks of the body chamber, a tendency for the tubercles to weaken near the aperture of the large, adult specimens." By contrast, *Teloceras* "has a coronate adult body chamber, its tubercles occur higher on the flanks and remain strong on the body chamber, and the adult body whorl contracts little or none at all from the preceding whorl."

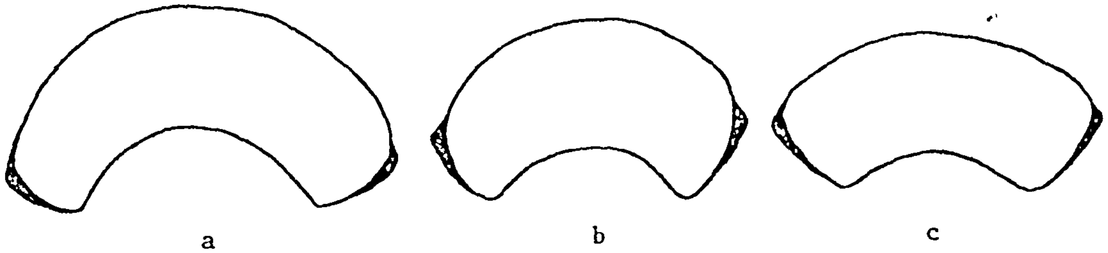
Several specimens of *Teloceras* cf. *multinodum* (Quenstedt) from

Goslar in north-western Germany have been compared with the inner whorls of specimens of *Z. richardsoni* from the Queen Charlotte Islands and southern Alaska. Clear differences are already apparent at diameters of 25 mm. In *Zemistephanus*, even at this early stage, the whorls are broader and more strongly arched than in *Teloceras*; the inner flanks are strongly convex and almost vertical on their lower parts, forming a deep, crater-like umbilicus, and the nodes are rather more blunt and much lower on the flanks (Text-fig. 6). At similar diameters, *T.* cf. *multinodum* is strongly coronate with a broad and only slightly arched venter, an abrupt lateral shoulder and steep inner flanks which, however, are not convex as in *Zemistephanus*. The umbilicus, then, is more open and conical. Primary ribs in *Teloceras* are more prominent, sharper and higher than those on *Zemistephanus* at the same growth stage, but the nodes are not as large or conical in form, representing instead sharp terminations of the primary ribs. On later growth stages the primary ribs are broader, but remain prominent, the nodes become large and rounded and secondary ribs are strong and relatively sharp. In cross-section the coronate form of *Teloceras* becomes more pronounced with a broad, flat venter. Near the end of the phragmocone, *Zemistephanus*, in contrast, exhibits a decline in the strength of ornamentation, primary ribs becoming broad undulations and the nodes blunt and rounded.

Zemistephanus [♀ , macroconch]

Following is a revised diagnosis and list of recognised species:

Diagnosis: Inner whorls cadiconic with broadly arched venter, well defined lateral shoulder with large, conical nodes and steep, convex



Text-fig. 6. Comparison of cross-section of phragmocone whorls in *Zemistephanus* and *Teloceras*. (a) *Z. richardsoni* ♀, MacKenzie Bay, Queen Charlotte Islands, McM J1797a, x 1, drawn at D = 70 mm. Whorl overlap of 40%. (b) *Z. richardsoni* ♀ , USNM 3000.1, Tuxedni Bay, southern Alaska, x 1, drawn at D = 62 mm. Whorl overlap of 33%. (c) *T.* cf. *multinodum* ♀ , Goslar, southern Germany, x 1, drawn at D = 63 mm. Whorl overlap of 25%.

flanks forming a deep, narrow umbilicus. Primary ribs broad, faint on lower flanks, with 3-6 secondary ribs to each primary arching forward on the venter. Body chamber egresses strongly with marked decrease in whorl width and rounding of the whorl section, usually three-quarters to one whorl in length. Aperture simple with flared collar.

Zemistephanus richardsoni (Whiteaves, 1876) ♀ , lower part of the Yakoun Formation, Queen Charlotte Islands and Fitz Creek Siltstone, southern Alaska.

Zemistephanus carlottensis (Whiteaves, 1876) ♀ , lower part of the Yakoun Formation, Queen Charlotte Islands; Fitz Creek Siltstone and Cynthia Falls Sandstone, southern Alaska.

Zemistephanus alaskensis n. sp. ♀ , lower part of the Yakoun Formation, Queen Charlotte Islands and Fitz Creek Siltstone, southern Alaska.

?*Zemistephanus warreni* (McLearn, 1930) ♀ , Fernie Formation, Porcupine

Creek, Kananaskis Valley, southern Alberta.

Zemistephanus [♂ , microconch]

The microconch form of *Z. richardsoni* is described here for the first time, from MacKenzie Bay. In all essential features it closely resembles those specimens from the same locality described by McLearn (1927) as *Kanastephanus*. Arkell (1957) placed *Kanastephanus* in synonymy with *Normannites* Munier-Chalmas, 1892, but *Kanastephanus* differs from that genus in having a deeper and narrower umbilicus, more coronate whorl section, large conical tubercles and denser secondary ribbing throughout the phragmocone. Westermann (1964a, p. 68) placed *Kanastephanus* in synonymy with *Itinsaites* McLearn, 1927; however, *I. itinsae* is here shown to be the microconch of *Stephanoceras yakounense* McLearn (pp. 134-5). The "microconch genus" *Kanastephanus* McLearn, 1927 is placed in synonymy with the corresponding macroconch, *Zemistephanus* McLearn, 1927. Following is a diagnosis for microconch *Zemistephanus* [♂] and a list of recognised species:

Diagnosis: Phragmocone cadiconic, whorl section strongly depressed with broadly arched venter, lateral shoulder and steep, convex flanks forming a deep, narrow umbilicus. Primary ribs broad, faint on lower flanks, with large, conical nodes along the lateral shoulder and 3-6 secondary ribs to each primary. Body chamber egresses and contracts, aperture with ventro-lateral lappets. Ornamentation strong to aperture but nodes lost and primary ribs bifurcate.

Zemistephanus richardsoni (Whiteaves, 1876) ♂, lower part of the Yakoun Formation, Queen Charlotte Islands and Fitz Creek Siltstone (possibly Cynthia Falls Sandstone also), southern Alaska.

Zemistephanus crickmayi (McLearn, 1927) ♂, lower part of the Yakoun Formation, Queen Charlotte Islands; Fitz Creek Siltstone and Cynthia Falls Sandstone, southern Alaska.

Zemistephanus richardsoni (Whiteaves, 1876) ♀ & ♂

(Pl. 1, figs. 1-6; Pl. 2, figs. 1-4; Text-figs. 7-15)

Zemistephanus richardsoni ♀

1876 *Ammonites richardsoni* Whiteaves, pp. 32, 33; Pl. 5, figs. 1, 2.

1927 *Zemistephanus richardsoni* (Whiteaves); McLearn, p. 63.

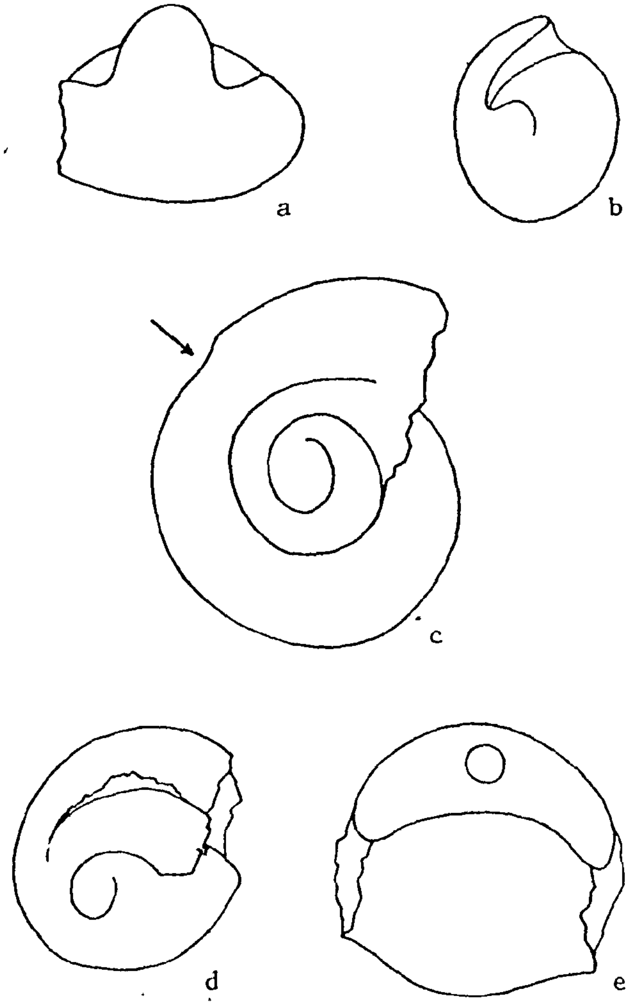
1929 *Zemistephanus richardsoni* (Whiteaves); McLearn, p. 19; Pl. 9, figs. 1, 2; Pl. 10, fig. 2.

1929 *Zemistephanus funteri* McLearn, p. 20; Pl. 10, fig. 1.

1964 *Zemistephanus richardsoni* (Whiteaves); Imlay, p. B51; Pl. 25, figs. 6, 7; Pl. 26, figs. 1-7.

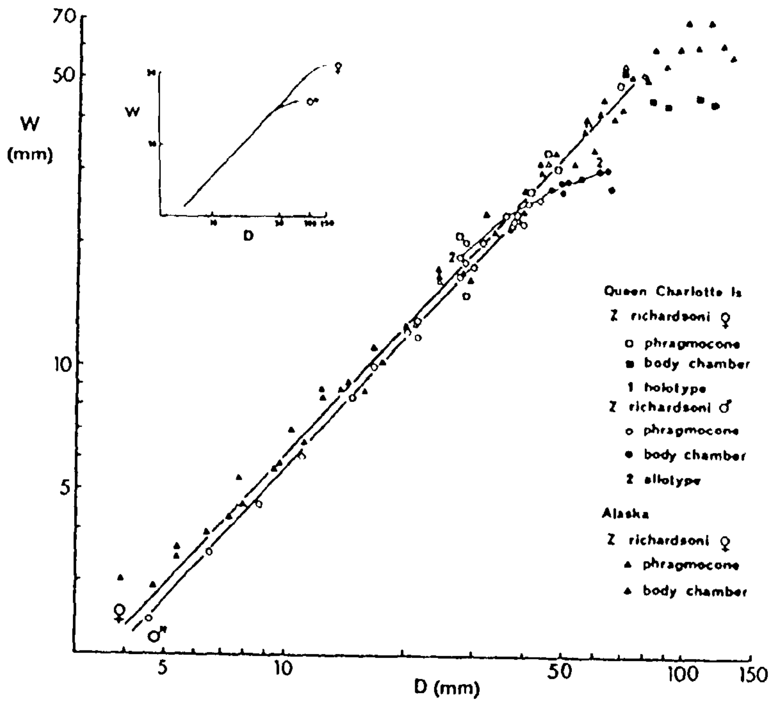
Holotype: GSC 1053, collected by J. Richardson in 1872, presumably from the lower part of the Yakoun Formation at MacKenzie Bay on the north shore of Maude Island, Skidegate Inlet, Queen Charlotte Islands (Text-fig. 1).

Material: Two complete specimens (McM J1797a, b), five reasonably complete specimens (McM J1797c-g) from Yakoun Formation, lower 5 m of the section



Text-fig. 7. Protoconch and first whorl of *Z. richardsoni* ♀ ; all x 62. (a) McM J1797i, ventral view of protoconch; (b) McM J1797i, lateral view of protoconch; (c) McM J1797h, first whorl with nepionic constriction at D = 0.8 mm; (d) McM J1797h, lateral view of protoconch and part of first whorl; (e) McM J1797h, ventral view of (d).

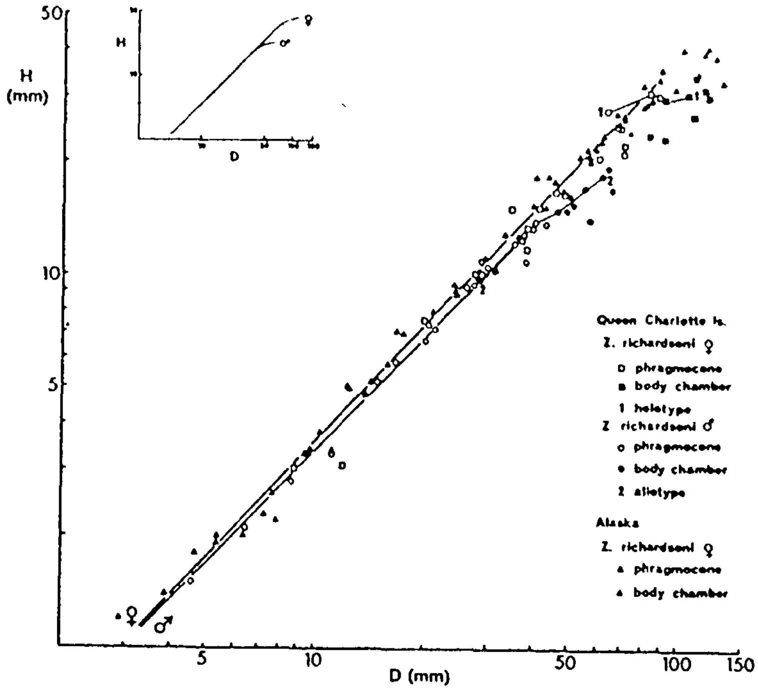
exposed at MacKenzie Bay; one specimen (McM J1797j) from shales 45 m above base of exposed section at MacKenzie Bay. The holotype (GSC 5013), McLearn's "plesiotype" (GSC 9006) and another specimen from this locality (GSC 13639) were re-examined. Seven specimens from the Fitz Creek Siltstone, southern Alaska (USGS Mesoz. locs. 2999, 3000, 10515, 26599).



Text-fig. 8. Plot of whorl width (W) against shell diameter (D) for *Zemistephanus richardsoni* (Whiteaves) ♀ & ♂ from Alaska and Queen Charlotte Islands. Measurements from 16 macroconch and 5 microconch specimens.

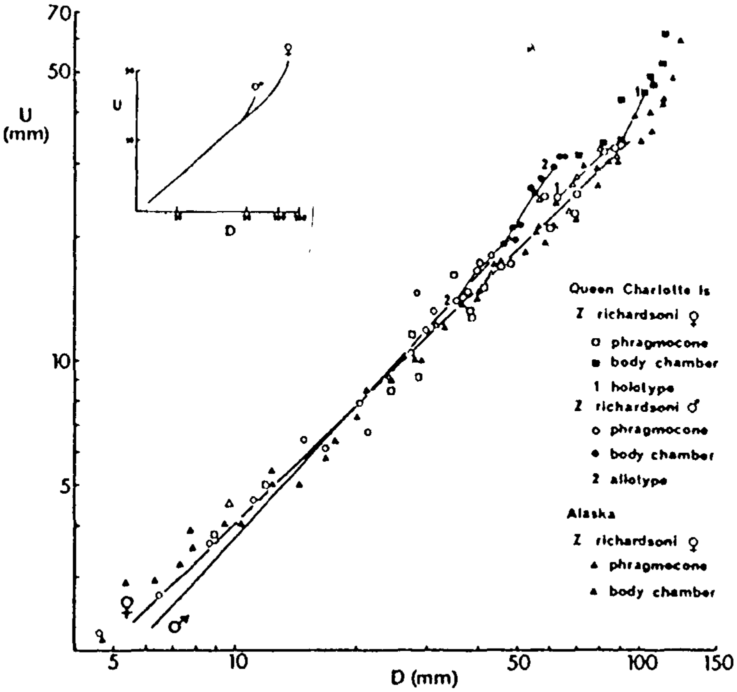
Description: Protoconchs were obtained from one Alaskan specimen (USGS Mesoz. loc. 2999) and two juvenile specimens from MacKenzie Bay (McM J1797h, i). The protoconch is smooth and transversely elongate with a width of about 0.5 mm and a height of 0.35 mm. The first whorl is smooth with a broad, flattened venter which curves abruptly near the umbilical seam to form a short, convex flank. One whorl after the prosuture at a diameter of 0.8 mm there is a broad, faint constriction on the venter which fades approaching the umbilical seam. The siphuncle at this stage has a relatively large diameter and is centrally situated (Text-fig. 7).

Immediately following the constriction a distinct lateral shoulder forms with steep, convex flanks falling to the umbilical seam. A change in shell dimensions occurs at the end of the first whorl with positive



Text-fig. 9. Plot of whorl height (H) against shell diameter (D) for *Zemistephanus richardsoni* (Whiteaves) ♀ & ♂ from Alaska and Queen Charlotte Islands. Measurements from 16 macroconch and 5 microconch specimens.

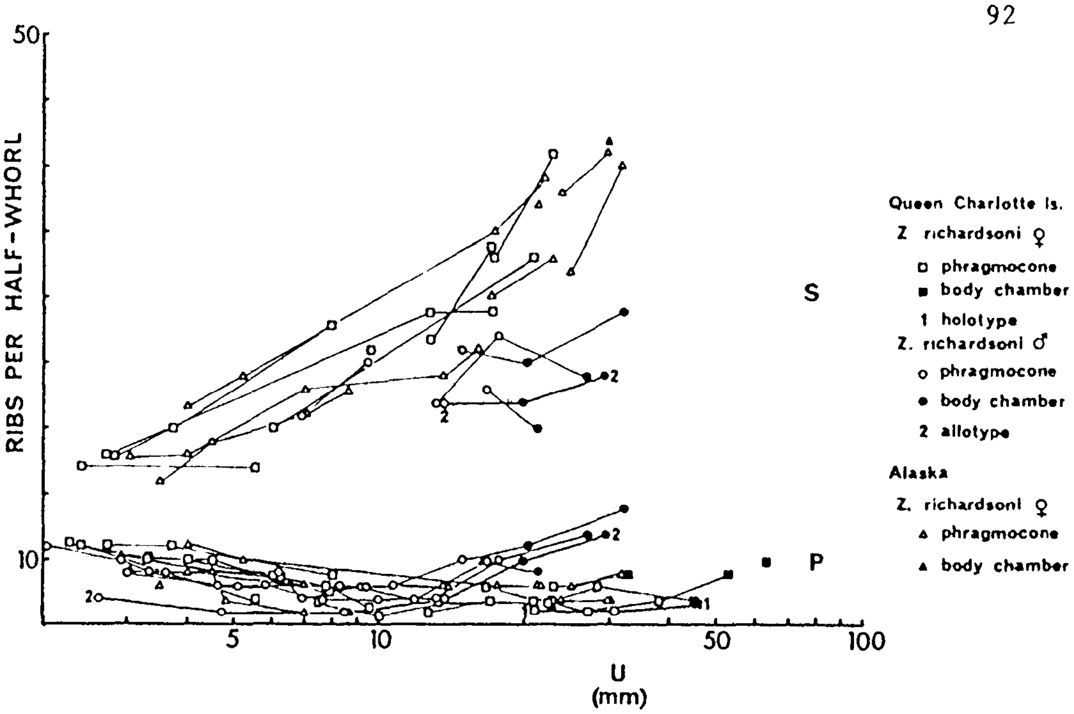
allometry for whorl height; growth ratios remain constant from this point to the end of the phragmocone. At a diameter of 1.5 mm small, elongated tubercles appear along the lateral shoulder and extend onto the upper flanks; they are strongly prorsiradiate. At a diameter of 4 mm faint secondary ribs appear; they are broad and rounded, usually two to each primary. At this stage the tubercles are prominent and conical and the primary ribs are broad, curved undulations of the flanks which still do not reach the umbilical seam. Whorl cross-section is depressed and coronate with H/W = 0.50-0.60. The venter is broad and only slightly arched while the flanks become very steep and almost vertical near the umbilical seam. Secondary ribs soon become sharper than the primaries and more densely spaced with increasing diameter, as many as 5 per primary.



Text-fig. 10. Plot of umbilical diameter (U) against shell diameter (D) for *Zemistephanus richardsoni* (Whiteaves) ♀ & ♂ from Alaska and Queen Charlotte Islands. Measurements from 16 macroconch and 5 microconch specimens.

Primary ribs become rectiradiate but are still massive and rounded with large, conical nodes; their spacing during ontogeny at first decreases from 8-12 per half-whorl to a minimum of 6-8 between umbilical diameters of 5 and 15 mm and then increases again to 8-10 on the final whorl (Text-fig. 11). Fine striae, which may entirely mask the secondary ribbing, appear on the outer shell surface of some specimens at diameters between 50 and 75 mm.

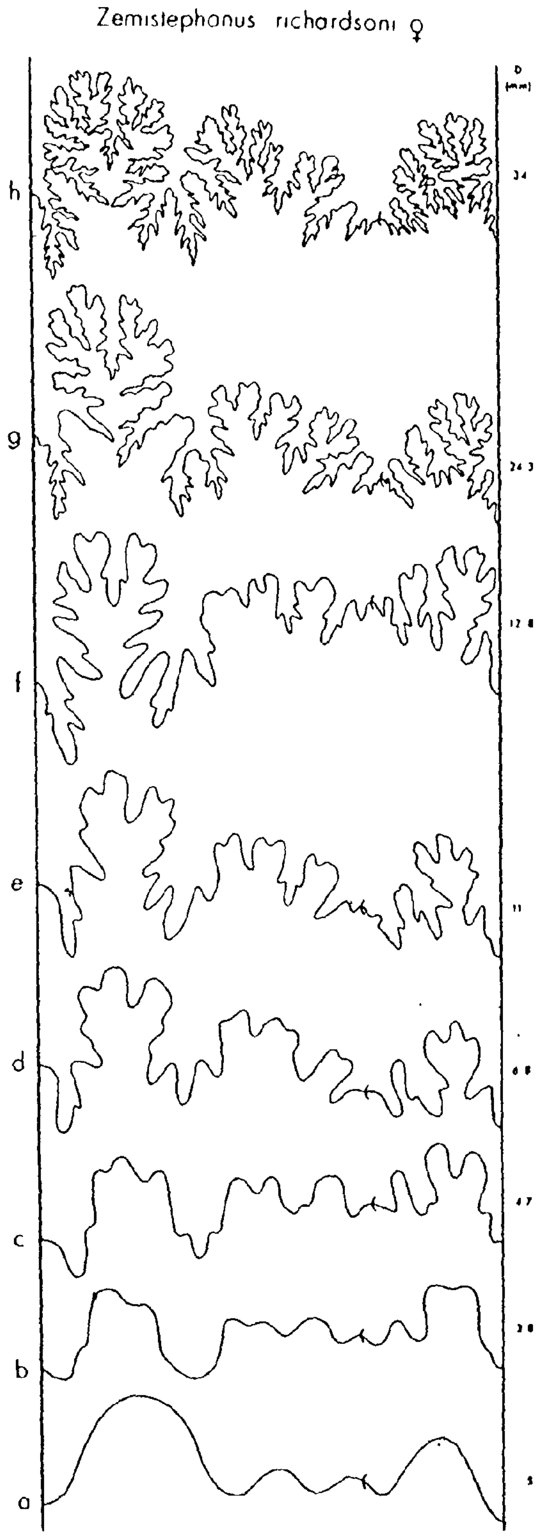
Marked changes in growth occur on the body chamber which is about one whorl in length. The umbilical seam egresses suddenly from the line of nodes on the previous whorl, the flanks become less steep and the relative (and sometimes absolute) whorl width descreases sharply, resulting in strong contraction of the whorl (Text-figs.8, 13). H/W ratios increase



Text-fig. 11. Plot of numbers of secondary (S) and primary (P) ribs per half-whorl against umbilical diameter (U) for *Zemistephanus richardsoni* (Whiteaves) ♀ & ♂ from Alaska and Queen Charlotte Islands.

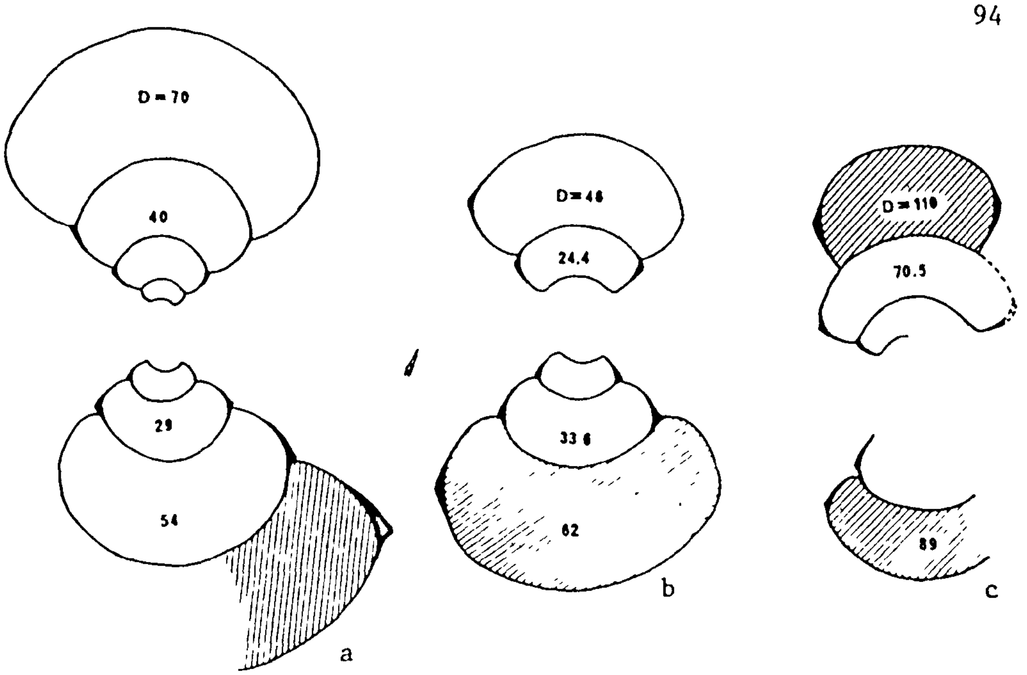
to as much as 0.75 with rounding of the cross-section. Both primary and secondary ribs become faint and may disappear entirely. Nodes are blunt and rounded but persist to the aperture, situated low on the whorl. The aperture is marked by a slight constriction followed by an expanded collar and complete lip.

Remarks: The specimens from southern Alaska and MacKenzie Bay agree closely in whorl shape, coiling and ornamentation (Text-figs. 8-11, 13). Most Alaskan representatives of the species attain larger sizes and have broader body chambers and coarser secondary ribs. The character of the nodes on the body chamber also varies, some becoming blunt and rounded while others remain high and fairly sharp.

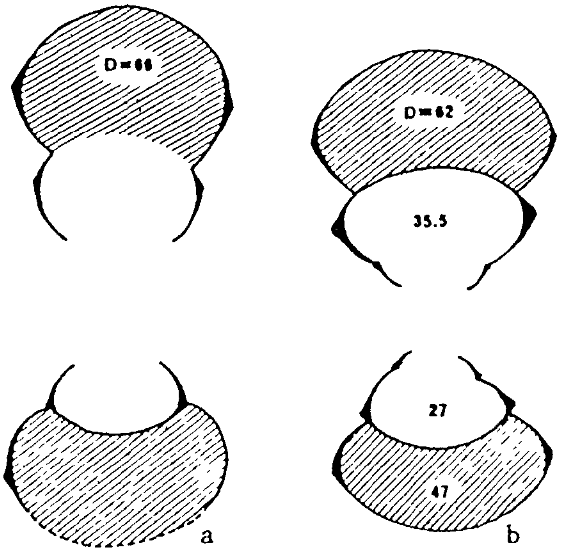


Text-fig. 12.

Sutural ontogeny for *Zemistephanus richardsoni* ♀
a-c: USGS Mesoz. loc. 2999.3
d-h: USGS Mesoz. loc. 26599.1



Text-fig. 13. Cross-sections through the phragmocone and body chambers (shaded) of *Zemistephanus richardsoni* (Whiteaves) ♀. (a) USGS Mesoz. loc. 3000.1, x 1; (b) USGS Mesoz. loc. 26599.1, x 1; (c) McM J1797a, x 0.5.



Text-fig. 14. Cross-sections through phragmocone and body chambers (shaded) of *Zemistephanus richardsoni* (Whiteaves) ♂. (a) McM J1796b, x 1 (approx.); (b) McM J1796a, x 1.

This species differs from *Z. carlottensis* (Whiteaves) in having more coronate whorls, losing strong secondary ribbing on the body chamber but retaining the large, conical nodes. *Z. alaskensis* n. sp. ♀ has similar phragmocone whorls but a higher body chamber whorl (H/W = 0.80-0.95) retaining strong secondary ribs with the nodes higher on the flanks.

Zemistephanus richardsoni ♂

This dimorph has not been previously described.

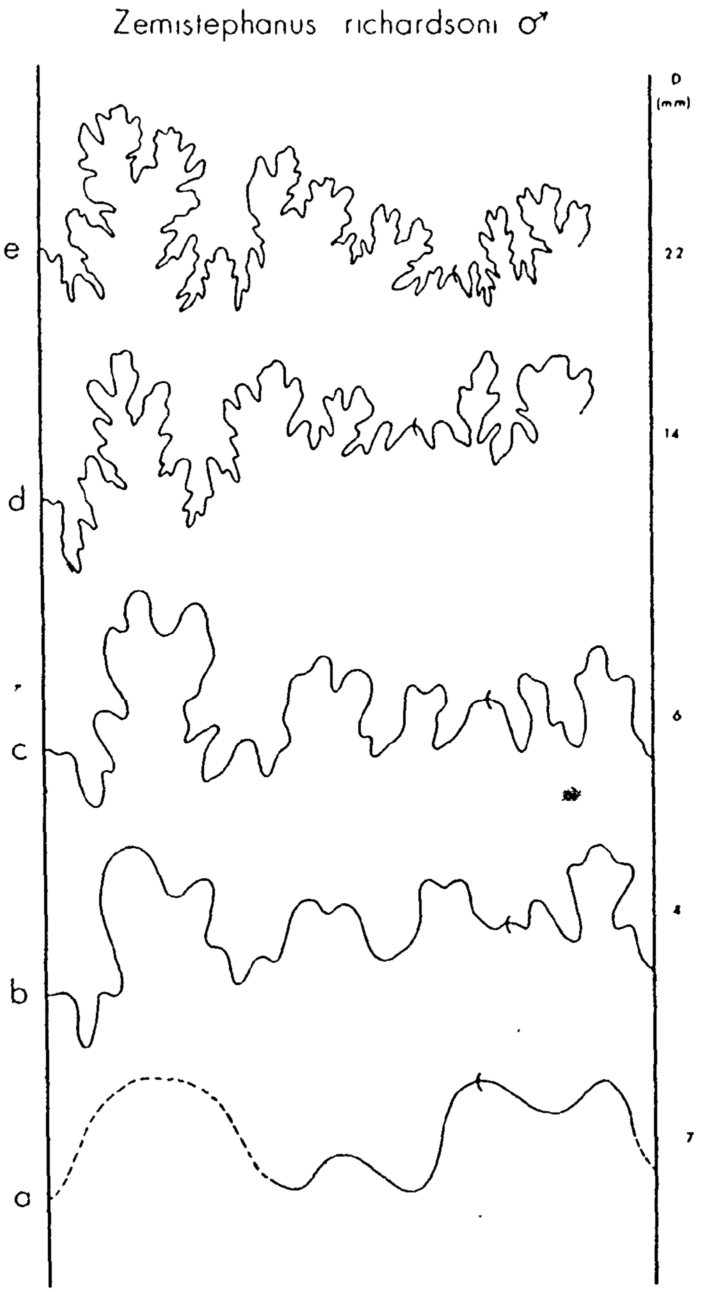
Allotype: McM J1796a, complete with lappets, from Yakoun Formation, lower 5 m exposed at MacKenzie Bay, Queen Charlotte Islands.

Material: Four specimens (McM J1796a-d), three complete with aperture, from lower 5 m of Yakoun Formation exposed at MacKenzie Bay, Queen Charlotte Islands; GSC 48593 from the same locality; two crushed specimens from the Fitz Creek Siltstone in southern Alaska, USGS Mesoz. locs. 2999, 26599.

Description: The nature of the protoconch and earliest whorls is unknown. At a diameter of 3-4 mm small, sharp tubercles appear along the lateral shoulder, extending onto the upper flanks as small ridges. The venter is smooth, broad and only slightly arched while the flanks are steep, falling straight to the umbilical seam. As diameter increases the tubercles become sharper and conical and the primary ribs extend further towards the umbilical seam; there are 9-10 per half-whorl. Broad, faint secondary ribs appear at a diameter of about 10 mm, two to each primary. At this stage the primary ribs take on characteristics which are retained throughout the phragmocone: they are broad, rounded undulations of the flanks, fading near the umbilical seam, rectiradiate and terminating in very high and sharp conical nodes on the lateral shoulder. Their number decreases to 6-8 per half-whorl between umbilical diameters of 5 and 15 mm, then later increases to 10-12 near the end of the phragmocone. Secondary ribs become strong, curving forward from the nodes, then crossing straight over the venter. Density of secondaries increases to 3 per primary (Text-fig. 11).

Whorl cross-section throughout the phragmocone is coronate with steep, convex flanks forming a deep, crater-like umbilicus. Nodes are situated at the point of maximum whorl width on the abrupt lateral shoulder which is at 40-50% of the total whorl height. H/W ratios throughout the phragmocone are 0.50-0.60.

The body chamber occupies about three-quarters of a whorl with egression from the line of nodes on the previous whorl commencing just after the last septum. While remaining broad and depressed in section, relative height increases on the body chamber, H/W ratios increasing to 0.62-0.64. Ribbing remains strong right to the aperture with only two secondaries to each primary and the loss of the high, conical nodes. Most primary ribs bifurcate simply at the point of maximum whorl width. Flanks are less steep than on the phragmocone whorls. Lappets are ventrolateral, short and spatulate with prominent growth lines (Pl. 2, fig. 1a); there is no strong constriction preceding the aperture and only weak flaring of the flanks.



Text-fig. 15.

Sutural ontogeny for *Zemistephanus richardsoni* ♂.
a–e: McM J1796d

Remarks: *Z. richardsoni* ♂ is distinguished from the four "species" of *Kanastephanus* described from this locality (McLearn, 1929) in having a broader living chamber (H/W of 0.62-0.64 vs. 0.68-0.74) and less arched venter. It also has more prominent conical nodes, broad rectiradiate primary ribs and steep, convex flanks; it resembles *Kanastephanus* spp. in the loss of nodes on the body chamber and decline of secondary rib density to two per primary.

Dimorphism: Comparison of whorl dimensions and ribbing pattern on the phragmocone whorls shows these specimens to be identical with the inner whorls of *Z. richardsoni* ♀ (Text-figs. 8-11, 13, 14; compare Pl. 1, figs. 5,6 with Pl. 2, figs. 1e, 3; Appendix 1) which occurs in the same beds both at MacKenzie Bay and in southern Alaska. Both show steep flanks with massive primary ribs and large, conical nodes, broad venter and similar changes in ribbing density at the same growth stages during ontogeny. Ornamentation of the body chamber, however, is quite different: while the microconch retains strong, bifurcating ribs but loses the sharp, conical nodes (Pl. 2, figs. 1a, 2a, 4) the macroconch has an almost smooth body chamber except for the large, rounded nodes low on the flanks (Pl. 1, figs. 1-3). Adult macroconchs are about twice the size of microconchs and in the MacKenzie Bay strata outnumber them approximately four to one.

Appendix 2 includes two sets of shell measurements selected from corresponding growth stages of macroconch and microconch phragmocones of *Z. richardsoni* and the results of statistical tests used for comparison of the growth patterns of these dimorphs. The second set of data (pp. 229 and following) indicates similar growth patterns in both dimorphs (identical slopes for regression lines at 95% level of confidence); the first set of data (p. 222) is shown to have unequal variances. This may indicate the need for further study as to how data should be selected in attempts to show identical growth gradients for supposed dimorphs using formal statistical testing; i.e. whether one should use regression statistics based on (a) "mass" curves in which numerous measurements are obtained from each individual at different growth stages; (b)"mass" curves in which only one measurement is obtained from each specimen; or, (c) individual growth curves using many measurements taken throughout the ontogeny of a single specimen representing each dimorph.

The intercept ("b" in the allometric equation: $Y = bX^a$) has a value (value of "b" when X = 1) whose biological meaning is uncertain. The inequality of "b" found in most of the growth patterns for dimorphs tested here may represent some real difference in shape of the embryonic growth stages of males and females; on the other hand dimensions and growth patterns on the first (nepionic) whorl of ammonites are known to diverge significantly from those found throughout the remainder of the phragmocone and so differences in "b" may have no biological significance.

Zemistephanus crickmayi (McLearn, 1927) ♂

(Pl. 3, figs. 1-5; Text-figs. 16-22)

1927 *Kanastephanus crickmayi* McLearn, p. 73; Pl. I, figs. 5, 6.

1929 *Kanastephanus crickmayi*; McLearn, pp. 23, 24; Pl. XVI, figs. 7, 8.

1929 *Kanastephanus canadensis* McLearn, p. 25; Pl. XV, figs. 4, 5.

1929 *Kanastephanus mackenzii* McLearn, p. 23; Pl. XVI, figs. 1-3.

1929 *Kanastephanus altus* McLearn, p. 24; Pl. XVI, figs. 4-6.

1949 *Normannites (Kanastephanus) crickmayi* McLearn; McLearn, pp. 13, 16.

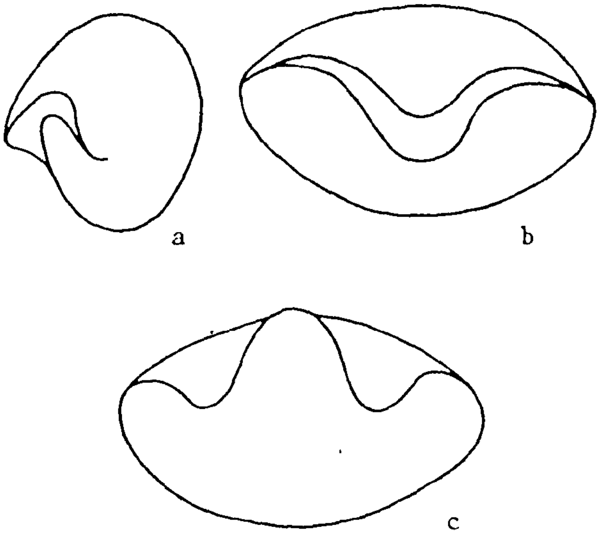
1954 *Itinsaites crickmayi* (McLearn); Westermann, pp. 290-292; Figs. 122, 123; Pl. 27, fig. 3.

1964 *Normannites (Itinsaites) crickmayi* (McLearn); Imlay, pp. B43, 44; Pl 14, figs. 3-8, 13.

1964 *Normannites (Itinsaites) itinsae* (McLearn); Imlay, p. B44; Pl. 14, figs. 1, 2.

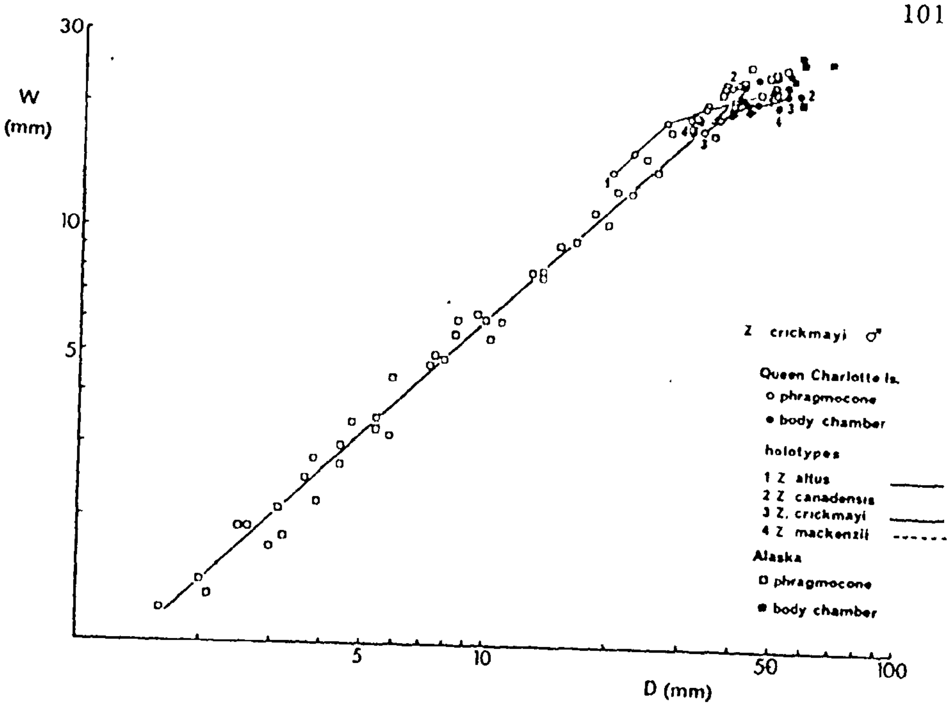
Holotype: GSC 9016, from the lower part of the Yakoun Formation on the north side of Maude Island, Queen Charlotte Islands, 10-22 ft. (3-7 m) above the base of the section exposed there (McLearn, 1929, p. 23).

Material: The holotypes of McLearn's four "species" of *Kanastephanus* (GSC 9016, 9017, 9018, 9019) have been re-examined; one additional complete specimen (McM J1798a) and a number of fragments (McM J1798b-h) were collected from the type locality at MacKenzie Bay. Six specimens from the Fitz Creek Siltstone in southern Alaska (USGS Mesoz. locs. 2999, 3000, 19997, 21276).



Text-fig. 16. Protoconch of *Zemistephanus crickmayi* (McLearn) ♂. Three views of the same specimen, USGS Mesoz. loc. 2999.4, x 62.

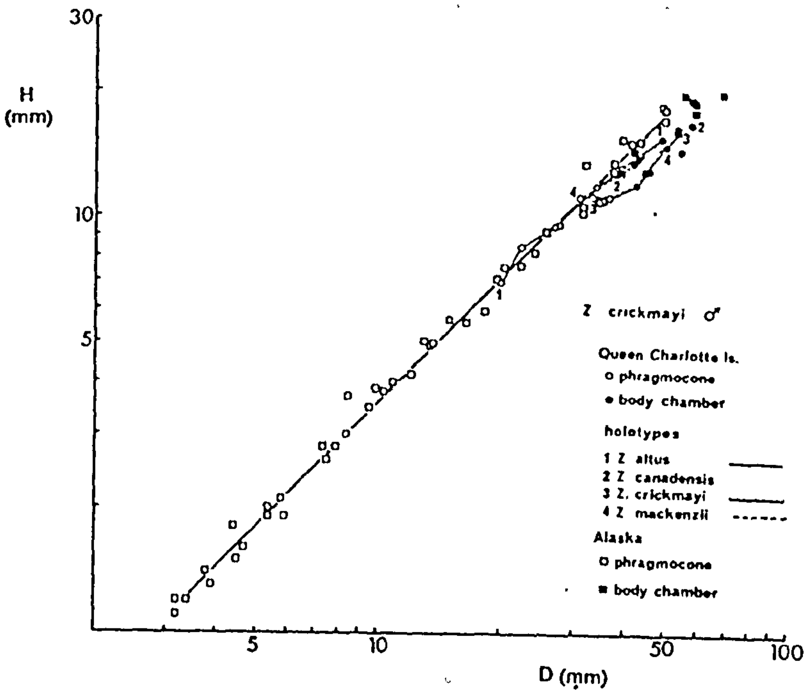
<u>Description</u>: The protoconch is smooth and elongated transverse to the plane of coiling; its width is about twice the diameter (Text-fig. 16). Though the nepionic constriction was not observed, after approximately one whorl (at D = 0.85 mm) there is a sudden decrease in relative whorl width and an increase in umbilical diameter. After this point growth ratios remain constant throughout the phragmocone (Text-figs. 17-19). On the first whorl the shell is smooth and globose with broadly arched venter and strongly convex flanks falling steeply towards the umbilical seam. The siphuncle is in a central position. At D = 3.0 mm small, elongated tubercles appear along the sharp lateral shoulder which is situated at about 30-40% of the whorl height. These elongated tubercles are directed adapicad onto the upper flanks. They also extend slightly onto the venter as faint, broad undulations when the diameter reaches 4.5 mm. There are 10 per half-whorl. The whorl cross-section is broad and depressed (H/W = 0.50-0.60) with a gently arched venter, sharp lateral shoulder



Text-fig. 17. Plot of whorl width (W) against shell diameter (D) for *Zemistephanus crickmayi* (McLearn) ♂ from the Queen Charlotte Islands and southern Alaska, including synonymous "species". Measurements from 13 specimens.

and steep, convex flanks. Secondary ribs soon extend right across the venter becoming much stronger than the primary ribs and outnumbering them two to one. Throughout the phragmocone the whorls remain broad and depressed with H/W ratios of 0.55-0.65.

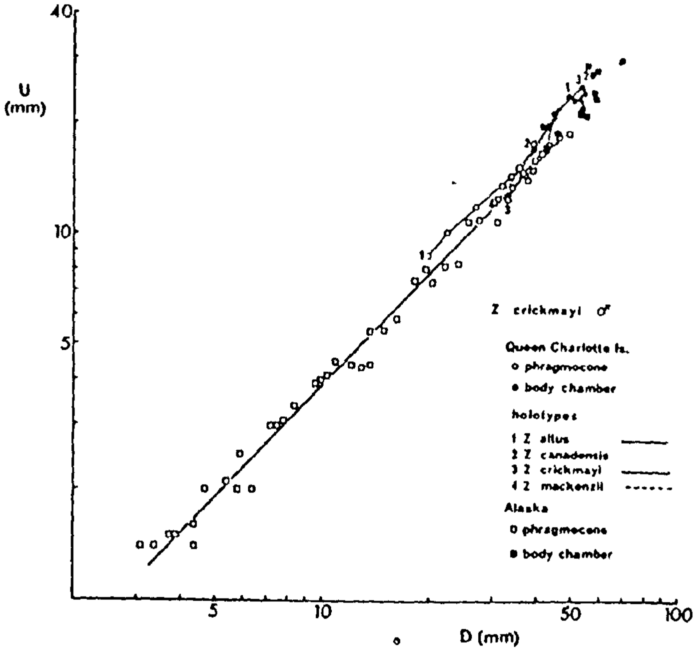
The number of primary ribs per half-whorl decreases from 10-13 on the earliest whorls to a minimum of 6-8 at umbilical diameters between 5 and 15 mm, then increases again to 8-12 at the end of the phragmocone (Text-fig. 20). At the same time the number of secondaries per half-whorl increases to a maximum, then declines on the body chamber. The ratio of secondary to primary ribs increases from 2 on the earliest whorls to 3 or 4 and then decreases on the body chamber to 2. Similar



Text-fig. 18. Plot of whorl height (H) against shell diameter (D) for *Zemistephanus crickmayi* (McLearn) ♂ from the Queen Charlotte Islands and southern Alaska, including synonymous "species". Measurements from 13 specimens.

variations in ribbing density during ontogeny were also noted on *Z. richardsoni* ♂ (p. 96). Primary ribs are broad and massive, but a little sharper and more curved than those on *Z. richardsoni* ♂; the nodes on *Z. richardsoni* ♂ are more massive and conical.

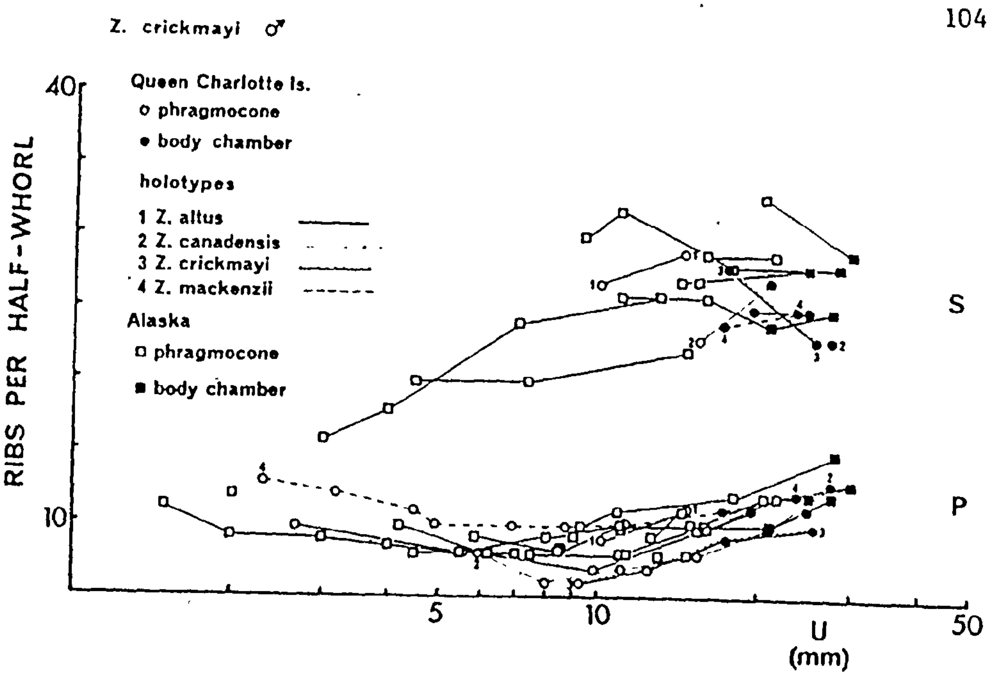
The body chamber is about one whorl in length and is marked by egression of the umbilical seam from the line of nodes on the previous whorl, changes in the shape of the cross-section and ornamentation. The flanks become less steep and the lateral shoulder more rounded with contraction of the whorl (Text-fig. 22); H/W increases to 0.65-0.75. Primary and secondary ribbing remains strong right to the aperture but the nodes disappear; primary ribs simply bifurcate. There is no



Text-fig. 19. Plot of umbilical diameter (U) against shell diameter (D) for *Zemistephanus crickmayi* (McLearn) ♂ from the Queen Charlotte Islands and southern Alaska, including synonymous "species". Measurements from 13 specimens.

constriction or flaring at the aperture which terminates with lateral lappets.

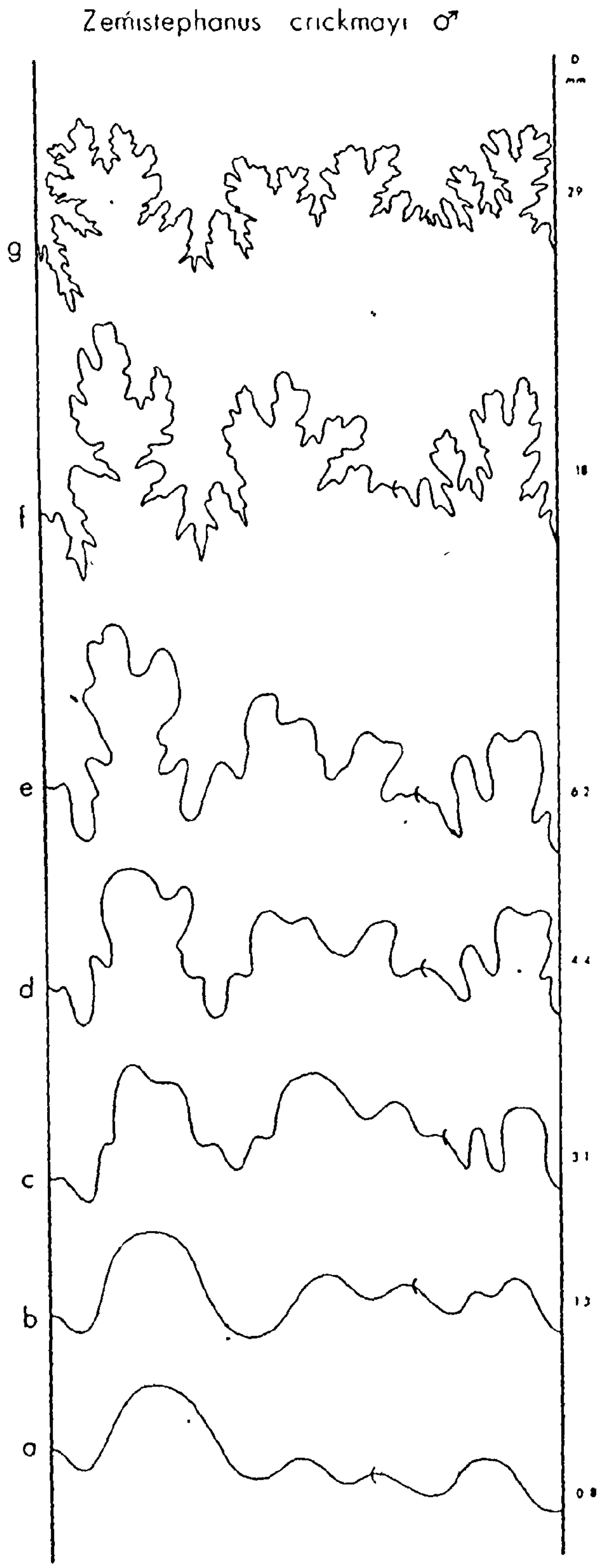
Remarks: The narrow body chamber clearly separates this species from *Z. richardsoni* ♂ which occurs in the same beds at MacKenzie Bay. There is only a slight increase in the H/W ratios on the body chamber of that species from 0.50-0.60 to 0.62-0.64 while the values for the same stages on *Z. crickmayi* ♂ are 0.55-0.65 and 0.65-0.75 respectively. The venter on the body chamber of *Z. crickmayi* ♂ is more highly arched, having a curvature radius of 80-100 mm at a diameter of 30 mm compared with a raduis of 140 mm for *Z. richardsoni* ♂ at the same size. In addition, the nodes on the phragmocone whorls of *Z. richardsoni* ♂ are more massive and the primary ribs broader and rectiradiate. In the material described



Text-fig. 20. Plot of number of secondary ribs (S) and primary ribs (P) per half-whorl against umbilical diameter (U) for *Zemistephanus crickmayi* (McLearn) ♂ from the Queen Charlotte Islands and southern Alaska, including synonymous "species".

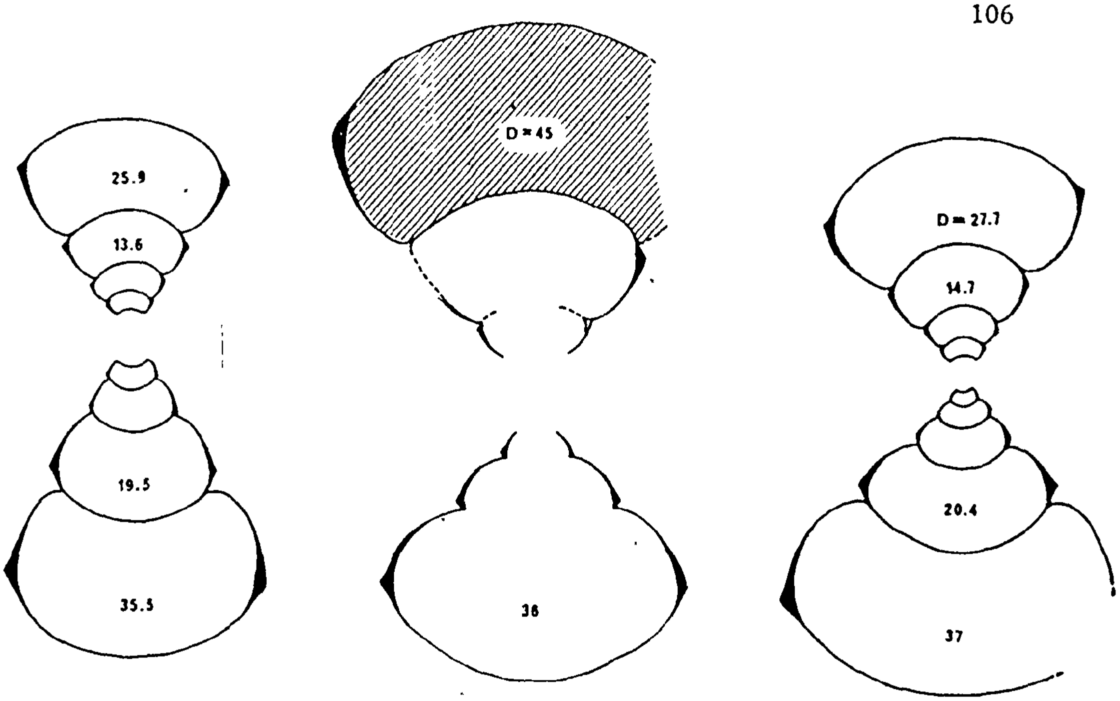
by Imlay (1964) as *N. (I.) crickmayi* (McLearn) from southern Alaska he notes a considerable variation in whorl width; this suggests that specimens of both *Z. richardsoni* ♂ and *Z. crickmayi* ♂ are present, but due to crushing are not easily distinguished.

McLearn (1929) distinguished four "species" in his genus *Kanastephanus* based on minor differences in coiling and ornamentation. *K. altus* supposedly has a higher whorl section and wider umbilicus but growth curves (Text-figs. 18, 19) show these differences to be very small and intermediate with values from other specimens. *K. mackenzii* was separated from the type species on the basis of more primary ribs but the number per half-whorl is the same as on *K. altus* and some of the Alaskan material. *K. canadensis* has slightly broader whorls than the other



Text-fig. 21.

Sutural ontogeny for *Zemistephanus crickmayi* (McLearn) ♂.
a-g: USGS Mesoz. loc. 2999.4



Text-fig. 22. Cross-sections through phragmocones and body chamber (shaded) of *Zemistephanus crickmayi* (McLearn) ♂. (a) USGS Mesoz. loc. 19997.0, x2; (b) McM J1798a, x 2; (c) USGS Mesoz. loc. 21270.1, x 2.

"species" but is identical in this character with McM J1798a from MacKenzie Bay as well as some of the Alaskan material. McLearn's four "species" were each based on a single specimen and the minor variations used to distinguish them are here shown to lie within the range of variation of all the available material representing Z. *crickmayi* (McLearn). ♂ (Text-figs. 17-20).

This species could be the microconch of Z. *carlottensis* (Whiteaves) ♀, the holotype of which probably came from the MacKenzie Bay locality. Both forms are characterised by coronate early whorls which contract strongly on the body chamber, losing the steep flanks. At the same time relative whorl height increases with stronger arching of the venter. Broad ribbing persists right to the aperture on both forms with a decline in the density of the secondaries to 2 per primary and loss of the prominent nodes. However, the only other macroconchs described are from southern Alaska (Imlay, 1964) and the few entirely septate specimens are too crushed to allow significant comparisons of whorl dimensions to be made.

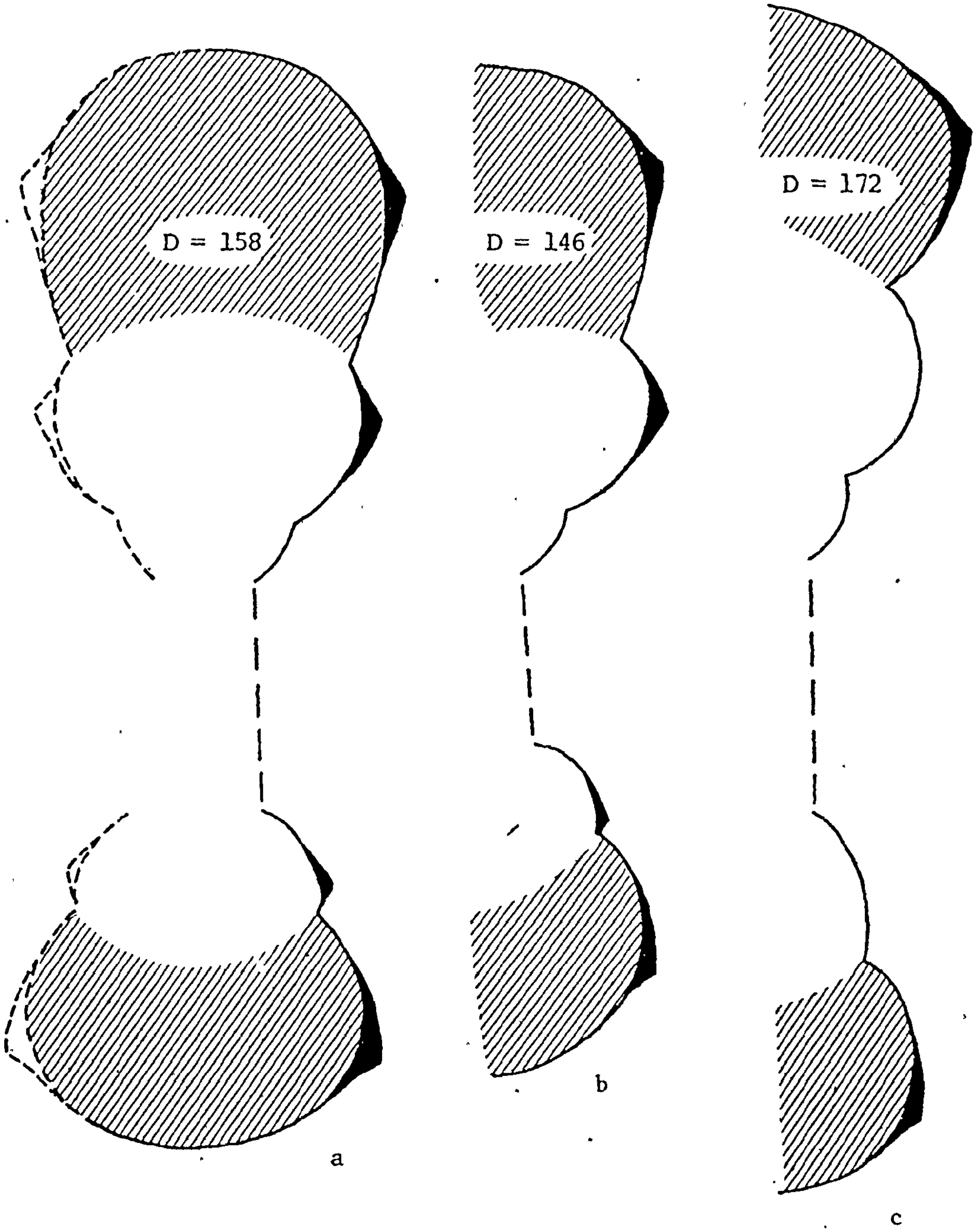
Zemistephanus alaskensis n. sp. ♀
(Pl. 3, fig. 6; Text-figs. 23, 24)

1964 *Teloceras itinsae* McLearn; Imlay, pp. B50, 51; Pl. 23, figs. 9, 10 [holotype]; Pl. 24, figs. 5, 7.

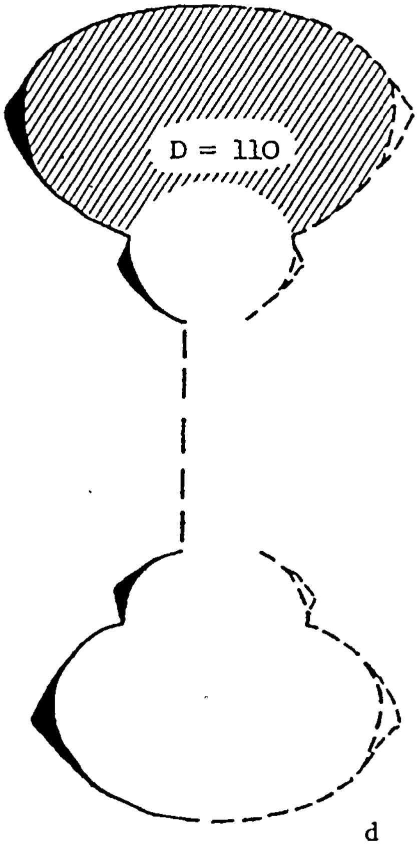
1964 *Zemistephanus richardsoni* (Whiteaves); Imlay, pp. B51, 52; Pl. 25, fig. 6; non Pl. 25, fig. 7; Pl. 26, figs. 1-7.

Holotype: USNM 131434, described and figured by Imlay (1964; Pl. 23, fig. 10) as a "plesiotype" of *Teloceras itinsae* McLearn, from USGS Mesoz. loc. 21270 in the Fitz Creek Siltstone of the Tuxedni Group, Tuxedni Bay, southern Alaska.

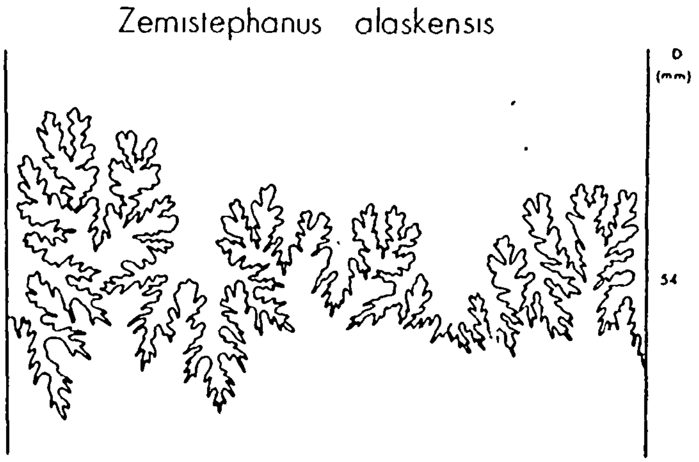
Material: Three other specimens from the Fitz Creek Siltstone in southern Alaska (USGS Mesoz. locs. 2999, 21270; McM J1245); two specimens (McM J1858a, 1858b) from shales 30 m above the base of the Yakoun Formation exposed at MacKenzie Bay and another (McM J1859) from 20 m above the base of the section.



Text-fig. 23. Cross-sections of phragmocone and body chamber (shaded) whorls of *Zemistephanus alaskensis* n. sp. ♀ from southern Alaska and the Queen Charlotte Islands. (a) USNM 131434, holotype, x 1, from USGS Mesoz. loc. 21270 in the Fitz Creek Siltstone; (b) USNM 131433, x 1, same locality



Text-fig. 23 (contd). as (a); (c) McM J1858a, lower Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands, x 1; (d) McM J1858b, x 1, from the same locality as (c).



Text-fig. 24. Suture line of *Zemistephanus alaskensis* n. sp. ♀ from southern Alaska and the Queen Charlotte Islands. USGS Mesoz. loc. 2999.2.

<u>Description</u>: A large macroconch reaching maximum diameter of at least 155 mm with a simple, slightly flared aperture. Phragmocone whorls coronate in cross-section, depressed (H/W = 0.55–0.65) with very steep flanks, producing a deep umbilicus. The venter is broad and gently arched, curving sharply onto the flanks along the line of nodes forming an abrupt lateral shoulder. Primary ribs are broad, rounded undulations of the flanks, rectiradiate or slightly curved forward on the inner whorls, 8-10 per half-whorl and ending in prominent, conical nodes. Secondary ribs are strong and broad, curving forward from the nodes and then crossing straight over the venter; usually 3-3.5 to each primary.

The body chamber is just a whorl in length and marked by similar changes in growth ratios as seen in other species of the genus. Egression of the umbilical seam from the line of nodes on the previous whorl begins just after the last septum; it is accompanied by strong contraction of the whorl with a marked decrease in the absolute whorl width and increase of whorl height so that H/W ratios change from 0.60-0.65 at the end of the phragmocone to 0.80-0.95 near the aperture. The flanks become less steep and are almost flat near the aperture while the undulations forming the primary ribs almost disappear. The conical nodes remain prominent right to the aperture but occur successively higher on the flanks: at 36% of the whorl height on the phragmocone, 40-45% on the early body chamber and 55-60% near the aperture. Strong, coarse secondary ribs persist to the end, usually 3-3.5 to each node. On two specimens (USNM 131437 and another from USGS Mesoz. loc. 21270) secondary ribbing is obscured by fine striae on the outer surface of the shell on the early parts of the body chamber.

Remarks: Coronate inner whorls with steep flanks, large conical nodes set low on the whorl and a gently arched venter are all features of the other known species of *Zemistephanus*. The marked egression of the body chamber with decrease in whorl width and flattening of the flanks, and the persistence of the large, rounded nodes to the aperture are also diagnostic of the genus. This species differs from *Z. richardsoni* (Whiteaves) ♀ in the persistence of secondary ribs to the aperture, the higher position of the nodes on the flanks and higher H/W ratios on the body chamber. Density of secondary ribbing on the phragmocone is lower and the ribs are much coarser than on *Z. richardsoni*.

Z. carlottensis (Whiteaves) ♀ also has a high whorl section with strongly arched venter on the body chamber, but differs from the present species in losing the large, conical nodes on the last part of the body chamber and having the point of rib bifurcation lower on the flanks (30-35% of the whorl height).

Marked egression of the body chamber and the strongly rounded cross-section at that stage clearly differentiate this species from *Teloceras*.

The corresponding microconch is unknown.

Subgenus *Stephanoceras* Waagen, 1869

Type Species: *Ammonites Humphriesianum* J. de C. Sowerby, 1825 by subsequent designation of Buckman (1898). Type specimen refigured by Buckman (1908; Pl. VII, fig. 1).

Discussion: The taxonomy of the group of ammonites closely allied to *Stephanoceras* Waagen has long been the subject of disputed and varied treatments, especially in Europe. Early difficulties arose in part because of doubt concerning the availability of the name *Stephanoceras* for an ammonite taxon; this was settled by Spath (1944) who pointed out that the closely similar spelling of another previously erected taxon in a very different group of organisms (*Stephanoceros*, Rotatoria) did not invalidate the name *Stephanoceras* as applied to the Bajocian ammonite genus. He also emphasised that the type species was

Stephanoceras humphriesianum (Sowerby, 1825) by a subsequent designation of Buckman (1898, p. 454).

Because he believed the name was pre-occupied, Buckman had emended *Stephanoceras* to *Stepheoceras*; while rejecting the need for this alteration Mascke (1907), however, retained both names, separating forms with a very wide umbilicus, weaker sculpture and a strongly enlarged aperture as *Stepheoceras* Buckman (group of *Amm. Humphriesi* Sow.). Those species with heavy sculpture, a deeper umbilicus and only slightly enlarged aperture (group of *Amm. Humphriesi mutabilis* Quenstedt) were described as *Stephanoceras* (Waagen) em. Mascke. In addition he proposed three new groups of closely related stephanoceratids: *Stemmatoceras*, *Skirroceras* and *Teloceras*.

Stemmatoceras (type species: *Amm. Humphriesianus coronatus* Quenstedt, 1886 [= *S. frechi* Renz, 1913] was to include forms with a mostly wide umbilicus, depressed whorls and medium-strong sculpture which declines on the body chamber, particularly with respect to the density of secondary ribbing. *Skirroceras* (type species: *Amm. Humphriesianus macer* Quenstedt, 1886) was separated from *Stemmatoceras* on the basis of a more strongly incised suture and wider, more shallow umbilicus. The whorls expand only slowly and are rounded in section with less inflated flanks on the body chamber. *Teloceras* (type species: *Amm. Blagdeni* J. Sowerby, 1818) was characterised by great whorl thickness with large nodes and a sharp lateral edge between venter and flanks; these characters persist onto the body chamber with only a decline in the strength of ornament near the aperture.

In his extensive review of the group Weisert (1932) recognised only three subgenera: *Stephanoceras* Waagen, 1869; *Stemmatoceras* Mascke, 1907; and *Teloceras* Mascke, 1907. He included Mascke's *Skirroceras* and *Stepheoceras*, along with many of Buckman's vast array of stephanoceratid "genera" (*Kallistephanus*, *Skolekostephanus*, *Rhytostephanus*, *Oecostephanus*, *Stegeostephanus*, *Mollistephanus*, *Kumatostephanus*) in *Stephanoceras* Waagen. In addition he gave a detailed discussion of the characters distinguishing each genus throughout ontogeny. Included under *Stephanoceras* Waagen were forms with a rounded whorl section, narrow to broad umbilicus, ribbing of variable strength and low, fine nodes; the suture was said to be strongly differentiated, with a greatly subdivided "1st lateral" saddle (? L/U). *Stemmatoceras* on the other hand was defined as having a little-differentiated suture (of which the "1st lateral" saddle was only weakly subdivided), strong, high and pointed nodes with a decrease in the strength of the sculpture on the body chamber. The whorls are not as rounded as in *Stephanoceras* and the venter is not as highly arched.

While following Weisert's treatment of these closely related forms, Schmidtill and Krumbeck (1938) again made clear reference to the existence of two groups within *Stephanoceras* Waagen as defined by Weisert. They emphasised the contrast between the group containing

S. umbilicum (Quenstedt), *S. duerbachense* Schmidtill and Krumbeck and *S. mutabile* (Quenstedt) having a deep umbilicus of medium width with broader whorls and the group including *S. humphriesianum* (Sowerby), *S. zieteni* Quenstedt and *S. scalare* Mascke which all have a fairly wide, shallow umbilicus, discoidal form and higher whorl section (p. 324). These two groups would correspond to "*Stephanoceras* Waagen emend. Mascke" and "*Stepheoceras* Buckman" respectively. Schmidtill and Krumbeck did not add further to the discussion of the genus *Skirroceras* Mascke, but unlike Weisert (1932) accepted as probably reasonable its separation from *Stephanoceras*.

The lectotype of *S. humphriesianum* (BM 43908a) is an entirely septate specimen cut along the sagittal plane; thus nothing is known of its adult size or body chamber characteristics. It does, however, have a rounded whorl section lacking any sign of a lateral shoulder, and a broad, shallow umbilicus with uncoiling commencing at least one complete whorl (at U = 20-25 mm) before the end of the specimen. Clearly this specimen is closer to the more serpenticone forms of *Skirroceras* than to the *S. mutabile* group and its choice as type species is unfortunate. Also, those forms with broader whorl section, less arched venter, stronger and sharper ornamentation and later uncoiling (often at U = 40 mm and corresponding to the beginning of the body chamber) bear close resemblance to *Stemmatoceras*. Indeed, Schmidtill and Krumbeck (1938, p. 325) noted that forms of *S. mutabile* "show a remarkable approach" to *Stemmatoceras*. Other members of this group would include *S. brodiaei* (J. Sowerby), *S. umbilicum* (Quenstedt), *S. itinsae* (McLearn) and *S. skidegatense* (Whiteaves). However, it must be emphasised that whatever character or combination of characters is used, there are transitional forms difficult to place confidently in one subgenus. There seems to be a morphological trend within the group for prolongation of the juvenile morphology into successively mature stages of the conch (Mouterde et al, 1971, p. 12). Thus in the early *Skirroceras* only the innermost whorls are rather involute cadicones; in *Stephanoceras* and *Stemmatoceras* these characters are present in successively later stages till in *Teloceras* most of them persist to the aperture. However, at any stratigraphic level a variety of morphological forms is usually present, only the proportions changing with time (Callomon, pers. comm.).

Although *Teloceras*, with its broad, coronate whorls persisting to the aperture, is clearly distinguishable in the adult stage, a number of specimens of this genus from western Europe and South America examined by me have juvenile whorls difficult to distinguish from those of the relatively broad-whorled *Stephanoceras* spp. This again emphasises the necessity of systematic distinctions being based on mature specimens with known body chamber characteristics; many European species have been erected for small, incomplete phragmocones, e.g. the small nucleus which is the type specimen of *S. umbilicum* Quenstedt makes proper interpretation of that species impossible. Similar situations have led to blurring of the distinctions between *Teloceras*, *Zemistephanus*, *Stemmatoceras* and *Stephanoceras* in North America.

In the Treatise on Invertebrate Paleontology Arkell (1957, p. 289) treated *Skirroceras* as a subgenus of *Stephanoceras* s. s. while retaining *Stemmatoceras* and *Teloceras* as separate genera. The great variety of *Stephanoceras* s. l. and the morphological resemblance of some species to *Stemmatoceras* require that *Stemmatoceras* also be classified as a subgenus of *Stephanoceras* Waagen. Indeed, many specimens from North America which have been identified with *Stemmatoceras* are here shown to be closely allied with the *Stephanoceras itinsae* group and thus also the broader-whorled European forms such as *Stephanoceras mutabile* (Quenstedt). *Stemmatoceras* is here treated as a subgenus of *Stephanoceras* due to the gradation in characters previously used to distinguish the two "genera".

Because of the close similarity in whorl dimensions, coiling and strength of the ribbing between Alaskan species previously described under *Skirroceras* (*S. kirschneri*, *S. nelchinorum*, *S. juhlei* Imlay spp.) and the lectotype of *Stephanoceras humphriesianum* (J. de C. Sowerby), these species are transferred to *Stephanoceras* s. s. If *Skirroceras* is to be retained as a subgenus of *Stephanoceras* it should be restricted to forms close to *S. (Skirroceras) macrum* (Quenstedt) which has round whorls with strong, sharp ornamentation.

Taxonomic treatment of microconch Stephanoceratidae has been varied. Westermann (1954) retained *Itinsaites* as a genus, making the Canadian species of *Kumatostephanus* synonymous with it. Arkell (1957,

p. L289) placed *Normannites* (which included *Itinsaites* and *Kanastephanus*, among others) in the family Otoitidae, a different family from that containing some genera since recognised as corresponding dimorphs (Stephanoceratidae). McLearn (1949) and Imlay (1964) both regarded *Itinsaites* as a subgenus of *Normannites;* Imlay also transferred the four Canadian species of *Kanastephanus* to *Itinsaites*, rightly suggesting that they probably represented a single species. However, it is shown here (p. 133) that all *Kanastephanus* spp. differ from *Itinsaites* and are in fact the corresponding microconchs to *Zemistephanus* McLearn ♀.

The pairing of macroconch-microconch genera in the family Stephanoceratidae was attempted by Westermann (1964a); microconch equivalents for *Stephanoceras*, *Stemmatoceras*, *Teloceras*, *Zemistephanus*, *Kumatostephanus* and *Cadomites* were sought in the several subgenera or related genera of *Normannites* Munier-Chalmas. *Itinsaites* McLearn is here shown to be the microconch equivalent to *Stephanoceras* s. s. part. Comparison of the inner whorls of *Itinsaites itinsae* McLearn and *Stephanoceras yakounense* McLearn from South Balch Island in the Queen Charlotte Islands indicates they are corresponding dimorphs (pp. 134-5). *Itinsaites* McLearn thus becomes a junior subjective synonym of *Stephanoceras* Waagen.

Stephanoceras itinsae (McLearn, 1927) ♀ & ♂

(Pl. 4, figs. 1-4; Pl. 5, figs. 1-4; Pl. 6, figs. 2-6;

Pl. 7, fig. 1; Text-figs. 25-33)

Stephanoceras itinsae ♀ [= "*Stephanoceras yakounense*"]

1900 *Perisphinctes skidegatensis* Whiteaves (part), p. 278.

1930 *Stephanoceras yakounense* McLearn, p. 5; Pl. 1, fig. 1 (holotype).

1932 *Stephanoceras yakounense*; McLearn, pp. 56-59; Pl. 2, fig. 1 (holotype); Pl. 3, figs. 2 (holotype), 4, 6 (holotype); Pl. 5, fig. 10.

1947 *Stemmatoceras mclearni* Warren, pp. 68, 69; Pl. I, fig. 1; Pl. IV, fig. 1.

1947 *Stemmatoceras carri* Warren, pp. 69, 70; Pl. IV, fig. 2; Pl. VI, fig. 3.

1957 *Stephanoceras* ex. gr. *skidegatense* (Whiteaves); Frebold, pp. 49, 50; Pl. XXI, fig. 1; Pl. XXII, fig. 2; Pl. XXV, fig. 2.

1957 *Stemmatoceras albertense* McLearn; Frebold, pp. 50, 51; Pl. XXI, figs. 2a, b; Pl. XXIII, figs. 1a-c.

1964 *Stephanoceras obesum* Imlay, pp. B45, 46; Pl. 18, figs. 5-11.

1967 *Stephanoceras* cf. *skidegatense* (Whiteaves); Imlay, p. 89; Pl. 6, fig. 10.

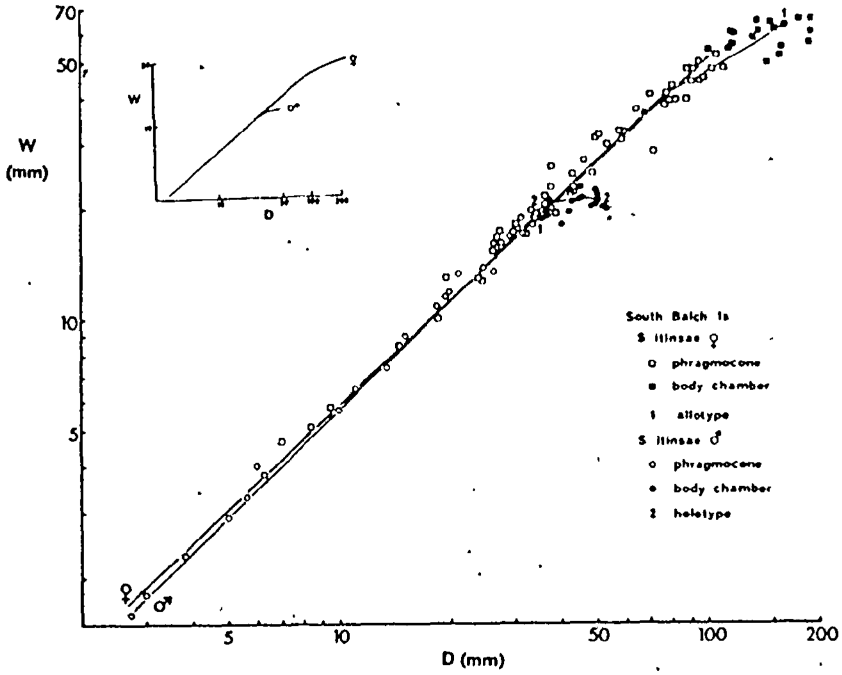
<u>Allotype</u>: GSC 9057, almost complete internal mold from lower part of the Yakoun Formation, South Balch Island, Skidegate Inlet, Queen Charlotte Islands [originally the holotype of *Stephanoceras yakounense*].

<u>Material</u>: Ten reasonably complete specimens (McM J1807-1811) and many

other phragmocone and body chamber fragments were collected from the type locality; also from this locality four specimens, three almost complete, collected by Sutherland Brown (GSC locs. 48601, 44711) and two collected by McLearn (GSC loc. 13634). One complete specimen and another with part of the body chamber collected by Sutherland Brown from Reef Island, Queen Charlotte Islands (GSC loc. 40985). Two specimens, one almost complete, on loan from University of British Columbia museum, labelled "Skidegate Channel". The holotype and McLearn's "plesiotype" were also re-examined.

Description:. Maximum diameters of adult macroconchs range from 148-196 mm. One body chamber fragment has a width of 66 mm at the position of the last septum and so must have attained a much greater diameter than any of the complete specimens examined; most adults reach a maximum width of only 60-65 mm at the aperture.

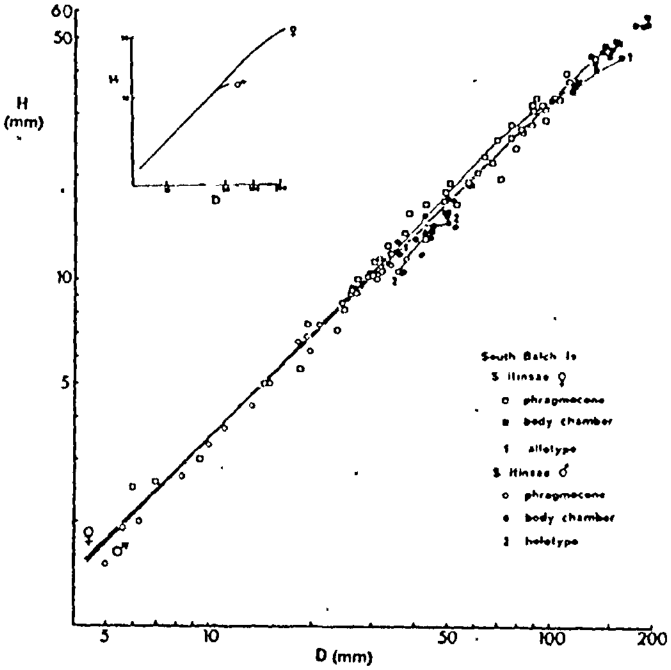
On the phragmocone the umbilical seam lies along the outer edge of the line of tubercles on the previous whorl. The whorls are much wider than high, with H/W = 0.55-0.60 at diameters up to 30 mm; throughout ontogeny the whorls gradually become higher with H/W = 0.65-0.70 between diameters of 30 and 100 mm. The flanks are strongly convex with strong primary ribs which are prorsiradiate and curved forwards, ending in prominent conical tubercles situated at about 50-65% of the whorl height and just above the point of maximum whorl width. The flanks curve strongly onto the broadly arched venter forming a lateral shoulder,



Text-fig. 25. Plot of whorl width (W) against shell diameter (D) for *Stephanoceras itinsae* (McLearn) ♀ & ♂ from Queen Charlotte Islands. Measurements from 15 macroconchs (13 from South Balch Island and 2 from Reef Island) and 11 microconchs (all from South Balch Island).

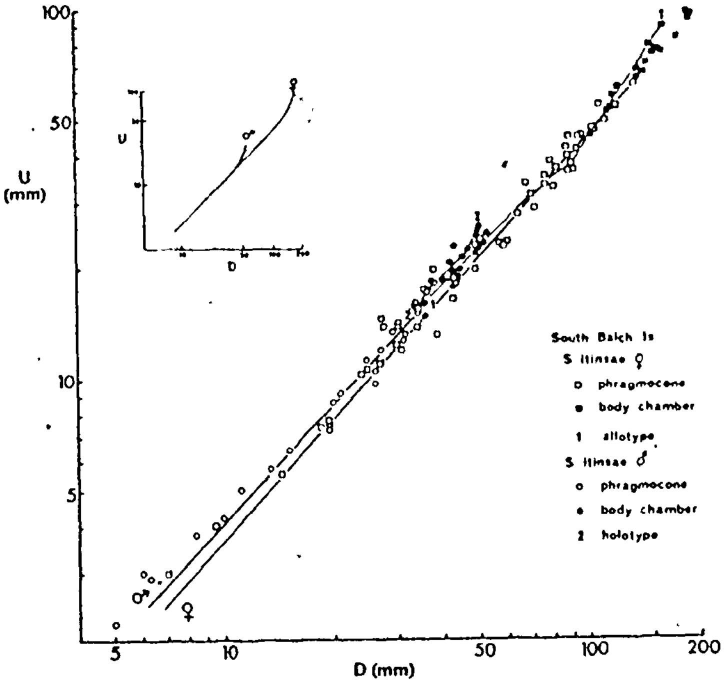
particularly on the phragmocone whorls. The number of primary ribs per half-whorl increases slowly throughout ontogeny from 9 at diameters up to 30 mm to 11 at 30-60 mm and 14 at 60-100 mm. The number of secondary ribs also increases from 3 per primary on the inner whorls to a maximum of 4-5 at diameters between 40 and 50 mm and declines again to 3 on the body chamber. Secondary ribs curve slightly forward from the tubercles then cross straight over the venter.

At diameters between 95 and 130 mm uncoiling begins (this corresponds to U = 35-55 mm), the umbilical seam moving gradually away from the line of tubercles, coiling thus becoming more serpenticone.



Text-fig. 26. Plot of whorl height (H) against shell diameter (D) for *Stephanoceras itinsae* (McLearn) ♀ & ♂ from Queen Charlotte Islands. Measurements from 15 macroconch (13 from South Balch Island and 2 from Reef Island) and 11 microconchs (all from South Balch Island).

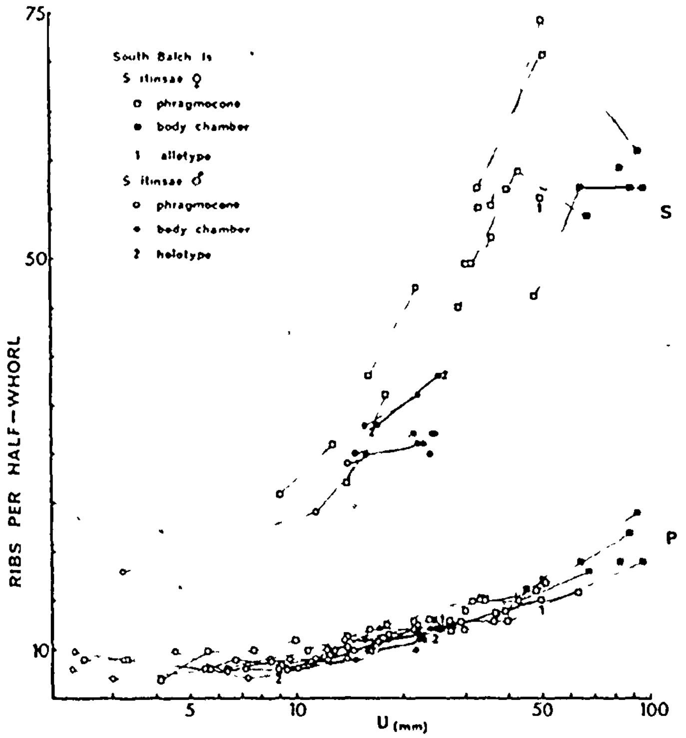
The point at which uncoiling begins also corresponds closely to the beginning of the adult body chamber which is usually three-quarters of a whorl in length. On the body chamber there is a decrease in relative whorl height and width (Text-figs. 25, 26), while the H/W ratio increases to about 0.75 and may be as high as 0.90. In cross-section the body chamber is oval with a more strongly arched venter than on the phragmocone, is almost as high as wide and has lost the strong lateral shoulder seen on the phragmocone. There are 16-26 (average 19) primary ribs on the final half-whorl and usually 3 secondaries to each primary rib. However, the secondary ribs are much fainter than the primary ribs while the tubercles become blunt and rounded and sometimes obsolescent near the



Text-fig. 27. Plot of umbilical diameter (U) against shell diameter (D) for *Stephanoceras itinsae* (McLearn) ♀ & ♂ from Queen Charlotte Islands. Measurements from 15 macroconchs (13 from South Balch Island and 2 from Reef Island) and 11 microconchs (all from South Balch Island).

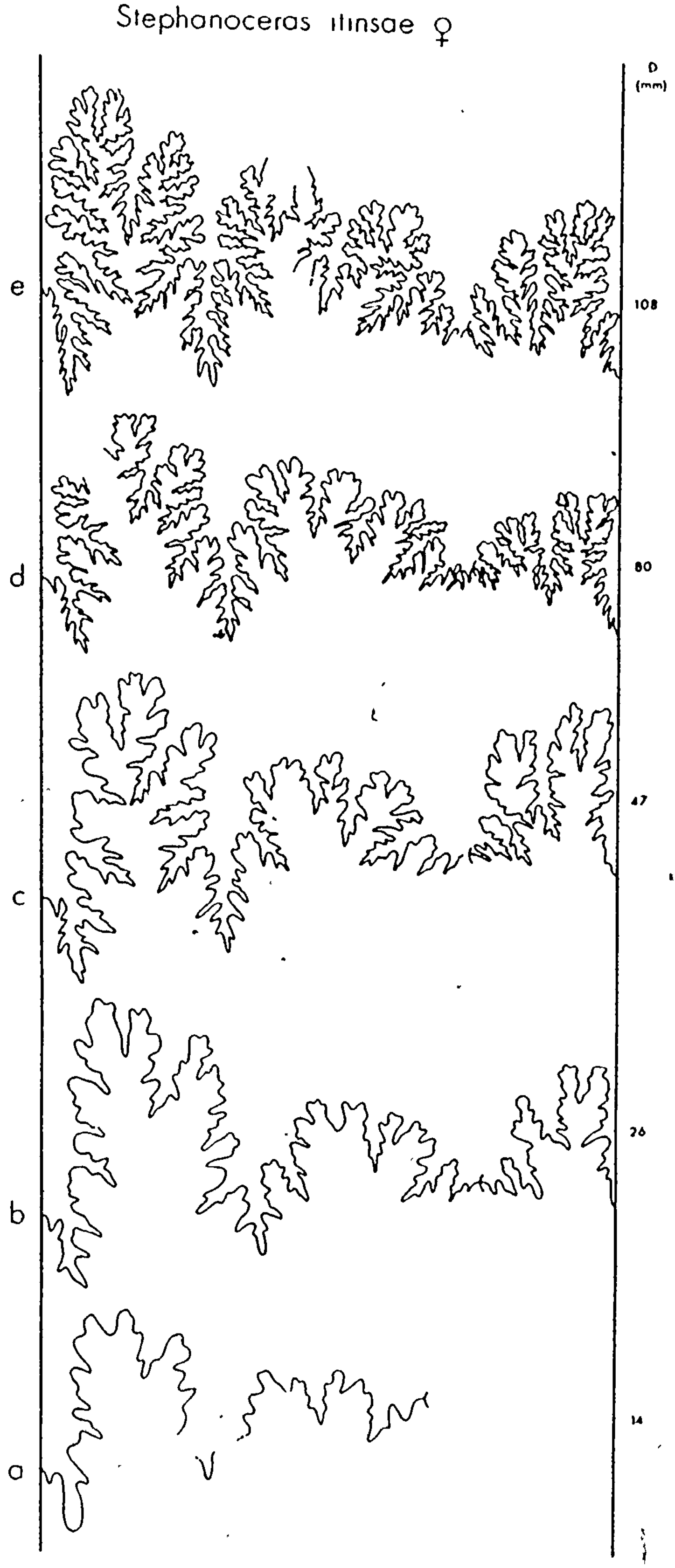
aperture. The primary ribs are shorter near the aperture, extending to less than 50% of the whorl height. The aperture is marked by a broad, shallow constriction and a slightly expanded, complete lip.

The suture is moderately deeply incised (Text-fig. 29). E is deep and narrow, L fairly broad, straight and trifid, almost as deep as E. Umbilical lobes strongly retracted; U_n is deep, narrow, trifid and oblique; I is much deeper and narrow. E/L is broad and high; L/U_2 is very broad and not nearly as high as E/L. The tubercle is situated on L/U_2.



Text-fig. 28. Plot of the number of secondary (S) and primary (P) ribs per half-whorl against umbilical diameter (U) for *Stephanoceras itinsae* (McLearn) ♀ & ♂.

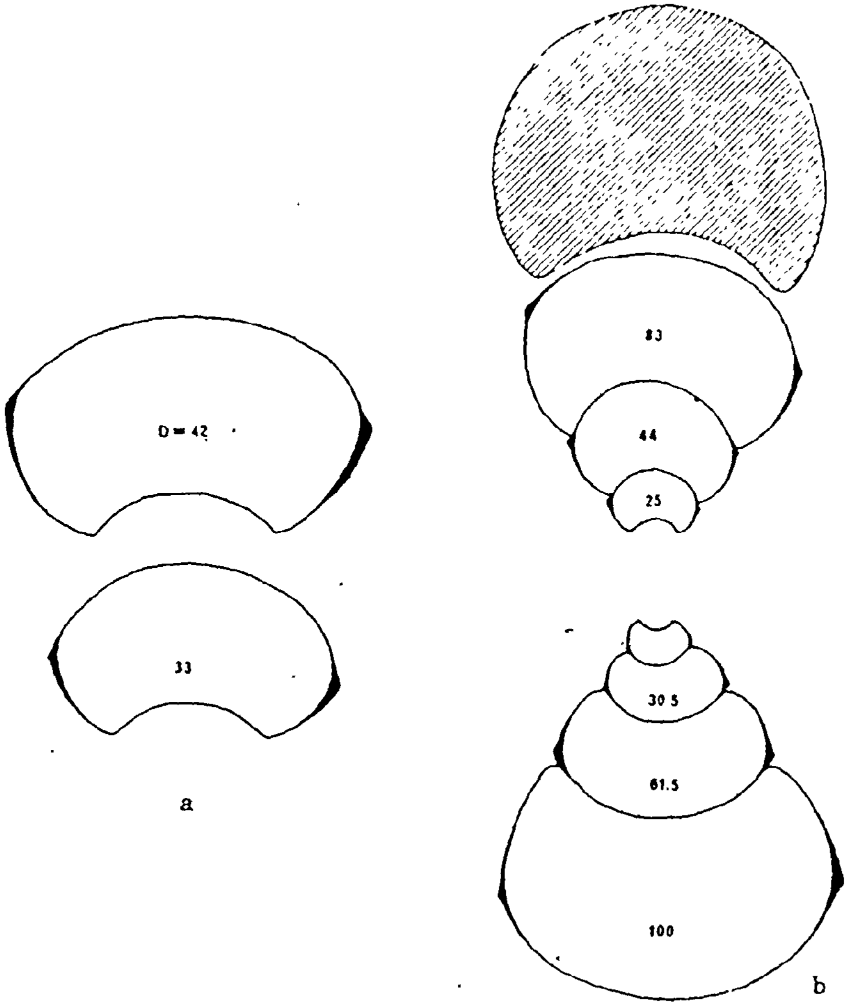
<u>Remarks</u>: *S. itinsae* ♀ strongly resembles the European species group including *S. umbilicum* (Quenstedt), *S. mutabile* (Quenstedt) and *S. brodiaei* (Sowerby) all of which are characterised by a relatively deep umbilicus with late uncoiling and broad whorls. *S. umbilicum* at similar diameters has a considerably smaller umbilical diameter (33% vs. 40-50% on *S. itinsae*), and relatively wider whorls (H/W of 0.58 vs. 0.68). *S. mutabile* has a less depressed whorl section than *S. itinsae* (H/W of 0.75 vs. 0.65-0.70 on *S. itinsae* at similar diameters). *S. itinsae* most closely resembles *S. brodiaei* differing only slightly in ornamentation: the holotype of *S. brodiaei* has fewer primary ribs (13 per half-whorl vs. 15-24 on *S. itinsae* at D = 105 mm). However, other specimens in the British Museum (Natural History) collections examined by me and regarded



Text-fig. 29.

Sutural ontogeny for *Stephanoceras itinsae* (McLearn) ♀.

a, b: McM J1810b
c, d: McM J1808g
e: McM J1809a



Text-fig. 30. Cross-sections of the phragmocone and body chamber (shaded) of *Stephanoceras itinsae* (McLearn) ♀ . (a) McM J1808g, x 2; (b) UBC specimen, x 1.

as conspecific with *S. brodiaei* have ribbing densities closer to those on *S. itinsae* ♀ . The tubercles on *S. brodiaei* are larger and more rounded than the sharp, pointed tubercles characteristic of *S. itinsae* ♀ .

The single specimen from the Rock Creek Member in Ribbon Creek, southern Alberta, described by Frebold (1957, pp. 50, 51) as *Stemmatoceras albertense* McLearn, is very similar to *S. itinsae* ♀ in whorl dimensions, coiling and the style and density of ribbing. The inner whorls are coronate, wider than high (H/W = 0.60-0.70 at D = 60 mm) with a broadly arched venter, distinct lateral shoulder and steep, convex flanks curving continuously to the umbilical seam which runs along the line of tubercles on the previous whorl. Primary ribs are strong and fairly sharp on the inner whorls, curving forward slightly with small, rounded tubercles at about 50% of the whorl height. The secondary ribs are also strong and sharp, passing almost straight over the venter from the tubercles. On the outermost preserved whorl (of which three-quarters is body chamber according to Frebold's description) the primary ribs become broader and less sharp but remain curved, the tubercles decline in strength and the secondary ribs are less sharp but still spaced 3 to each primary. The increase in the density of secondary ribbing from 3 to 4 per primary at diameters between 40 and 50 mm with the subsequent decline to 3 on the body chamber matches similar ontogenetic variation in *S. itinsae* ♀ .

Two other specimens described and figured by Frebold (1957, pp. 49, 50; Pl. 21, fig. 1; Pl. 22, fig. 2; Pl. 25, fig. 2) as *Stephanoceras* ex. gr. *skidegatense* (Whiteaves) are more probably synonymous with *S. itinsae* ♀ , having three secondary ribs to each primary on the adult whorls; these secondary ribs are broad, rounded and faint, not sharp as on *S. skidegatense* ♀ .

The holotype of *Stemmatoceras mclearni* Warren (UA Jr 192) is very similar to *S. itinsae* ♀ in coiling and ribbing. The umbilicus appears to be shallower and the flanks less convex, but due to poor preservation the actual whorl dimensions are difficult to estimate.

Stephanoceras obesum Imlay, from the lower part of the Tuxedni Formation in the Talkeetna Mountains of southern Alaska (Imlay, 1964, pp. B45, 46) has almost the same whorl dimensions as *S. itinsae* ♀ on the phragmocone whorls (H/W values of about 0.70), though the body chamber of the Alaskan material is unknown. Both have closely similar rib densities and style of ornamentation; secondaries on *S. obesum* are finer and sharper.

Stephanoceras itinsae ♂ [= "*Itinsaites itinsae*"]

1927 *Itinsaites itinsae* McLearn, p. 73; Pl. I, fig. 7 (holotype).

1929 *Itinsaites itinsae*; McLearn, pp. 26, 27; Pl. XV, figs. 2, 3 (holotype).

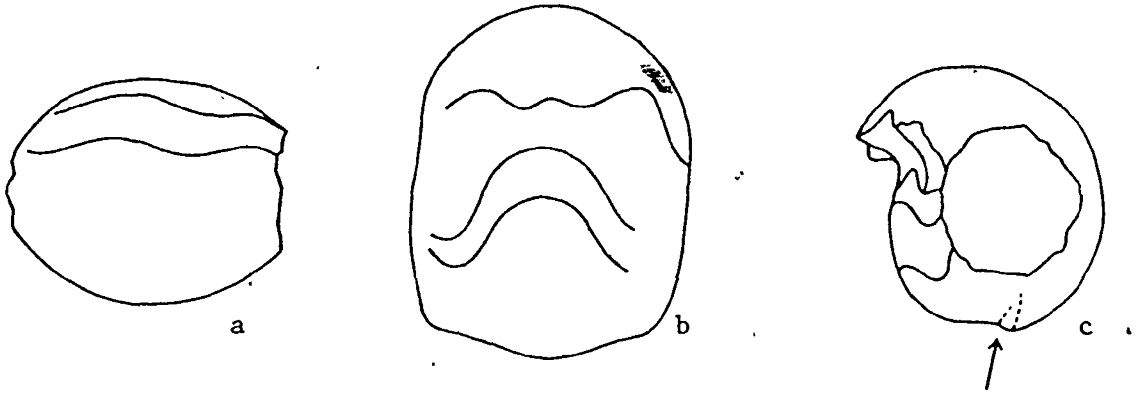
?1933 *Otoites reesidei* Crickmay, p. 912; Pl. 27, figs. 9-11.

1949 *Normannites (Itinsaites) itinsae* (McLearn); McLearn, pp. 15, 16.

1954 *Itinsaites itinsae* McLearn; Westermann, pp. 251-254; Pl. 26, fig. 5a, b (holotype refigured); Pl. 27, fig. 1a, b; Text-figs. 101-107.

Holotype: GSC 9020, from the lower part of the Yakoun Formation, South Balch Island, Skidegate Inlet, Queen Charlotte Islands.

Material: The holotype was re-examined along with three other complete specimens from the GSC collections, Ottawa, which came from the type locality (GSC locs. 13634, 48601). Four complete specimens (McM J1799a-c,

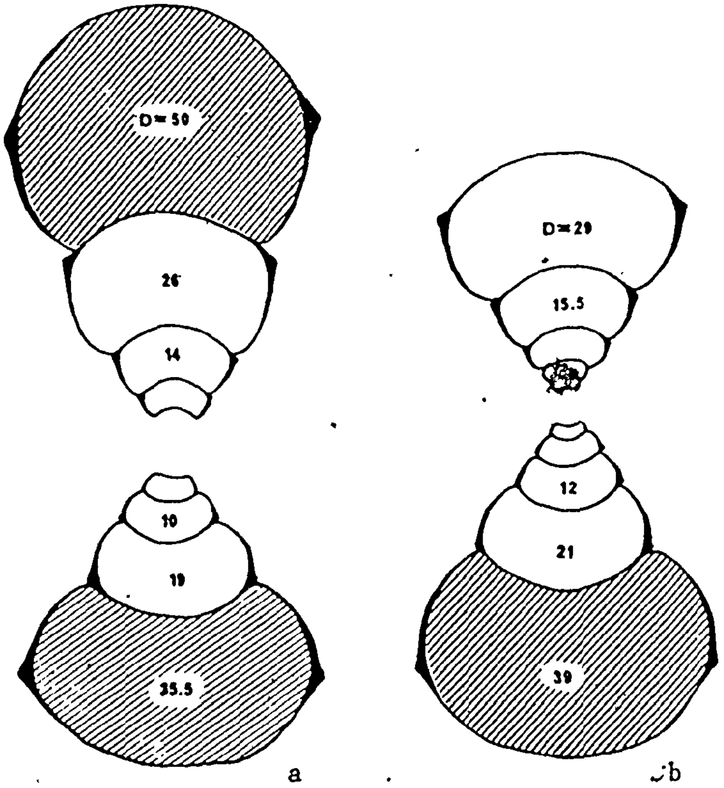


Text-fig. 31. Protoconch and first whorl of *Stephanoceras itinsae* (McLearn) ♂.(a), (b) McM J1800, x 75, protoconch showing two closely spaced protosepta and the primary suture; (c) McM J1800, x 30, first whorl with arrow indicating position of nepionic constriction at D = 0.8 mm.

J1800) and numerous fragments and incomplete phragmocones (McM J1799d, J1801a, b and J1810b) were collected by me from the type locality.

Description: The protoconch is cigar-shaped, elongated transverse to the plane of coiling, being more than twice as wide as high (H/W = 0.43) with a diameter in the plane of coiling of 0.43 mm (Text-fig. 31). At a diameter of 0.8 mm the nepionic constriction, seen clearly on the venter, marks the end of the first whorl (Text-fig. 31).

The shell is smooth until a diameter of 2.5 mm is reached. The first ornamentation consists of broad secondary ribs and small tubercles along the lateral shoulder; primary ribs are faint. By D = 6 mm strong, curved primary ribs extend from the umbilical seam to the lateral shoulder where they terminate in large, conical tubercles; two secondary ribs arise from each tubercle and at this stage in growth are stronger and sharper than the primary ribs. Whorls are much wider than high



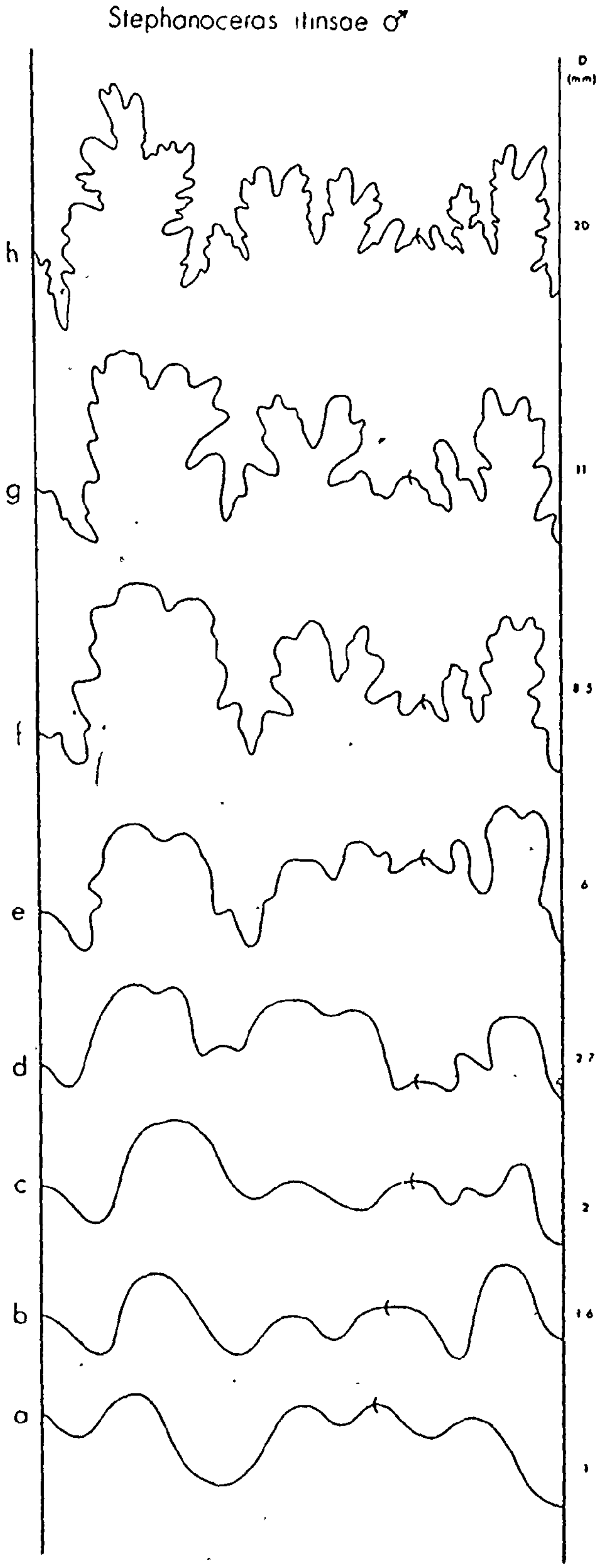
Text-fig. 32. Cross-sections of phragmocone and body chambers (shaded) of *Stephanoceras itinsae* (McLearn) ♂. (a) McM J1799a, x 2; (b) McM J1800, x 2.

(H/W ratios of 0.50–0.60) with a broad, slightly arched venter, pronounced lateral shoulder and gently convex flanks curving gradually to the umbilical seam which runs just on the ventral side of the row of tubercles on the previous whorl.

Throughout the phragmocone the whorls are coronate in cross-section, wider than high with a broadly arched venter (Text-fig. 32); the line of tubercles and the position of the pronounced lateral shoulder are a little higher on the flanks than the position of maximum whorl width (as measured between the primary ribs). Secondary ribs remain sharp, stronger than the primary ribs, and increase in density from two per primary to three and even four. Primary ribs are strongly curved forward reaching their maximum strength in the centre of the flanks and becoming weaker towards the umbilical seam and also towards the tubercles; the latter are large, conical and sharp. The number of primary ribs per half-whorl increases gradually from 8 at diameters below 30 mm to 10 at diameters between 30 and 40 mm.

The body chamber is half a whorl or a little more in length, but conspicuous uncoiling occurs only in the last quarter-whorl before the aperture where the umbilical seam moves away from the line of tubercles on the previous whorl. This is accompanied by a decrease in relative whorl height and width, with a marked change in the cross-section which becomes rounded with loss of the marked lateral shoulder. There is an increase in the H/W ratio from 0.60 at the end of the phragmocone to 0.70-0.80 just behind the aperture. Ornamentation on the body chamber remains strong, the sharp, curved primary ribs now being stronger than the secondaries. There are 10-12 primary ribs on the last half-whorl with 2.5-3.0 secondary ribs to each primary; tubercles become a little less sharp but are still prominent. The aperture is marked by a narrow constriction with a flared lip extending into long, lateral lappets. Maximum diameters of about 50 mm are attained.

On the single protoconch obtained there are two closely spaced protosepta showing the large, rounded ventral saddle with adjacent narrow lobes on the external suture (Text-fig. 31). U_n appears high on the



Text-fig. 33.

Sutural ontogeny for *Stephanoceras itinsae* (McLearn) ♂.

a-h: McM J1800

ventral flank of I/U_1 at a diameter of 2 mm. The mature suture is not deeply dissected; E is deep and narrow, L short, broad and trifid and the umbilical lobes strongly oblique. E/L is high and broad and not deeply dissected (Text-fig. 33). The tubercle lies on the ventral edge of L/U_2.

Remarks: McLearn (1929, pp. 26, 27) separated this species from the other lappet-bearing stephanoceratids on the Queen Charlotte Islands (i.e. "*Kanastephanus*"spp.) on the basis of the greater density of secondary ribbing. "*I. itinsae*" maintains a 3:1 ratio of secondary to primary ribs on the body chamber but on "*Kanastephanus*" this ratio declines to 2:1. All other material known from South Balch Island has densities of 3:1. The number of primary ribs per half-whorl increases gradually during ontogeny from 8 to 12 whereas on "*Kanastephanus*" this number shows an initial decrease from 10-13 to 6-8 with an increase to 8-12 again on later parts of the phragmocone. In addition, the primary ribs on the phragmocone of "*I. itinsae*" are sharper and more strongly curved than those of "*Kanastephanus*" and the tubercles are smaller and sharper, persisting onto the body chamber while on "*Kanastephanus*" the tubercles are lost on the body chamber where the ribs bifurcate simply.

Two partially preserved specimens from the Rock Creek Member of the Fernie Group (UA Jr 491, 494) were tentatively placed in "*Itinsaites*" by Warren (1947, p. 73). Inspection of the figures (Pl. VI, fig. 2; Pl. VII, fig. 2) indicates ribbing densities similar to those of *"Itinsaites"* but the growth stage is unknown. One complete specimen, (McM J1838) from the Rock Creek Member at Ribbon Creek, southern Alberta, shows the body chamber with three secondary ribs to each primary. The body chamber is a little wider than on the specimens from the Queen Charlotte Islands. Other incomplete small specimens from the Ribbon Creek locality probably also belong to this species.

The single specimen figured by Imlay (1964; Pl. 14, figs. 1, 2) as *N. (I.) itinsae* (McLearn) from the Fitz Creek Siltstone, southern Alaska is almost fully septate with only a small part of the body chamber. On the last half-whorl preceding the body chamber the density of the secondary ribs has already declined to 2.4 per primary which is characteristic of *Zemistephanus* ♂.

Otoites reesidei Crickmay from the Mormon Formation, Mt. Jura, California is very close to *S. itinsae* ♂ in most features except that in the former the density of secondary ribs on the preserved part of the body chamber declines to 2.5 per primary whereas on specimens of *S. itinsae* ♂ the density usually remains at 3.0.

Dimorphism: Dimensions and growth patterns throughout the phragmocone whorls of the macroconch and microconch agree closely (Text-figs. 25-27; Appendix 1, 2; compare Pl. 5, figs. 1c, d with Pl. 6, figs. 4c-f); shape of the whorl cross-section is also similar (compare Text-figs. 30, 32). The pattern and density of primary and secondary ribbing correspond closely (Text-fig. 28), both dimorphs showing a gradual increase in the density of secondary ribs from 2 to 4 per primary with a decrease to 3 in later growth stages. This 3:1 ratio is maintained on the body chamber of the microconch (Pl. 6, figs. 2, 3, 4a, 6a) though on the macroconch ornamentation declines in sharpness and the tubercles almost completely disappear near the aperture (Pl. 4, figs. 1-4). In both dimorphs the body chamber uncoils slowly, becoming relatively higher and rounder in cross-section with loss of the lateral shoulder.

These dimorphs occur together on South Balch Island (Table 5; Text-fig. 1), the macroconch being approximately 3-4 times the size of the microconch and almost four times as abundant. Specimens of both dimorphs also occur together in the Rock Creek Member of the Fernie Group at Ribbon Creek in southern Alberta. The specific epithet "*itinsae*" 1927 has precedence over "*yakounense*" 1930; the species is renamed *Stephanoceras itinsae* (McLearn, 1927).

Stephanoceras skidegatense (Whiteaves, 1876) ♀ & ♂

(Pl. 7, figs. 2, 3, 6; Pl. 8, fig. 1; Text-figs. 34-40)

Stephanoceras skidegatense ♀

1876 *Ammonites Skidegatensis* Whiteaves, p. 34; Fig. 4; Pl. 7.

1884 *Perisphinctes Skidegatensis*; Whiteaves, p. 210.

1900 *Perisphinctes skidegatensis*; Whiteaves, p. 278.

1932 *Stephanoceras skidegatense* (Whiteaves); McLearn, p. 54; Pl. I, fig. 2; Pl. 2, fig. 3; Pl. 3, figs. 8, 9.

1932 *Stephanoceras skidegatense* var. *laperousii* McLearn; pp. 54, 55;

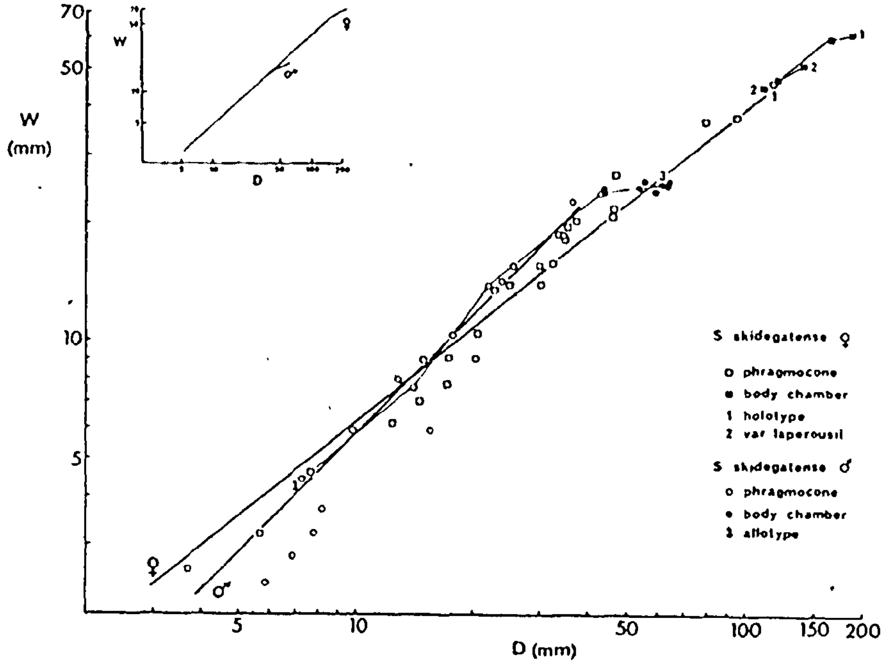
Pl. 1, fig. 1; Pl. 3, fig. 3.

Holotype: GSC 5011, collected by J. Richardson at Skidegate Inlet, 1872. No details of the precise locality are known. However, the only other specimens from the Queen Charlotte Islands referrable to this species have all been collected from the lower parts of the Yakoun Formation at Richardson Bay on the south shore of Maude Island (Text-fig. 1).

Material: Two large body chamber fragments and a number of incomplete phragmocones have been collected by me and by Sutherland Brown from the Richardson Bay locality.

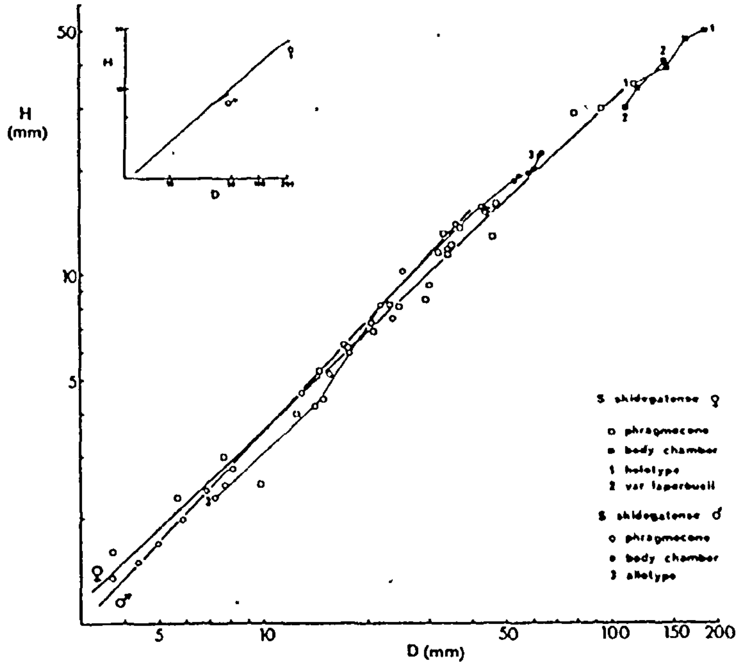
Description: The inner whorls are coronate in cross-section, being much wider than high (H/W ratios average 0.65 up to diameters of 60 mm) with a broadly arched venter curving sharply onto the flanks which are at first flat and steep. During ontogeny the flanks become more inflated with gradual rounding onto the venter which is more highly arched.

Ribbing is very sharp and strongly developed throughout. At diameters less than 30 mm there are 9-12 primary ribs per half-whorl, strongly prorsiradiate with prominent, conical tubercles. There are 2.5 secondaries to each primary. During growth the number of primary ribs increases slowly to 15 per half-whorl and the density of secondaries increases to 2.5-3.5 per primary.



Text-fig. 34. Plot of whorl width (W) against shell diameter (D) for *Stephanoceras skidegatense* (Whiteaves) ♀ & ♂ from Richardson Bay, Queen Charlotte Islands. Measurements from 12 macroconch and 3 microconch specimens.

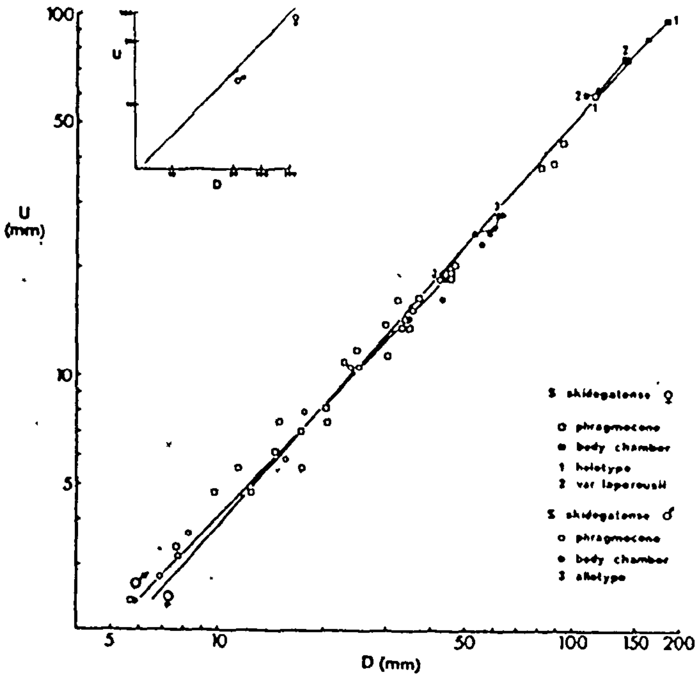
The length of the body chamber is so far unknown as complete specimens with aperture have not been found; it is in excess of three-quarters of a whorl. Uncoiling to serpenticone condition begins at about 100 mm diameter but the umbilical seam moves only slowly away from the line of tubercles on the previous whorl. The body chamber is relatively higher and rounder than the phragmocone whorls, becomes oval in cross-section (H/W = 0.75). Ribbing remains strong and sharp right to the aperture but the tubercles are reduced to slight laterally-elongated swellings on the flanks. Secondary ribs remain as strong as the primaries but decrease in density till there are only 2-2.5 per primary. There is also a loss of bifurcation, most secondaries arising by intercalation and lacking any connection with the tubercles; it is not uncommon for primary ribs to continue right over the venter.



Text-fig. 35. Plot of whorl height (H) against shell diameter (D) for *Stephanoceras skidegatense* (Whiteaves) ♀ & ♂ from Richardson Bay, Queen Charlotte Islands. Measurements from 12 macroconch and 3 microconch specimens.

One body chamber fragment collected by me shows a small part of the apertural margin which consists of a simple, flared lip preceded by a broad and very shallow depression on the flanks only.

Remarks: In whorl dimensions and ribbing this macroconch is closely allied with *S. itinsae* ♀ from the South Balch Island locality. However, the decline in the density of secondary ribbing and tubercle strength and the persistence of strong, sharp secondary ribs on the body chamber of *S. skidegatense* ♀ allow the two species to be separated at maturity. So far they have not been found together at any locality.



Text-fig. 36. Plot of umbilical diameter (U) against shell diameter (D) for *Stephanoceras skidegatense* (Whiteaves) ♀ & ♂ from Richardson Bay, Queen Charlotte Islands. Measurements from 12 macroconch and 3 microconch specimens.

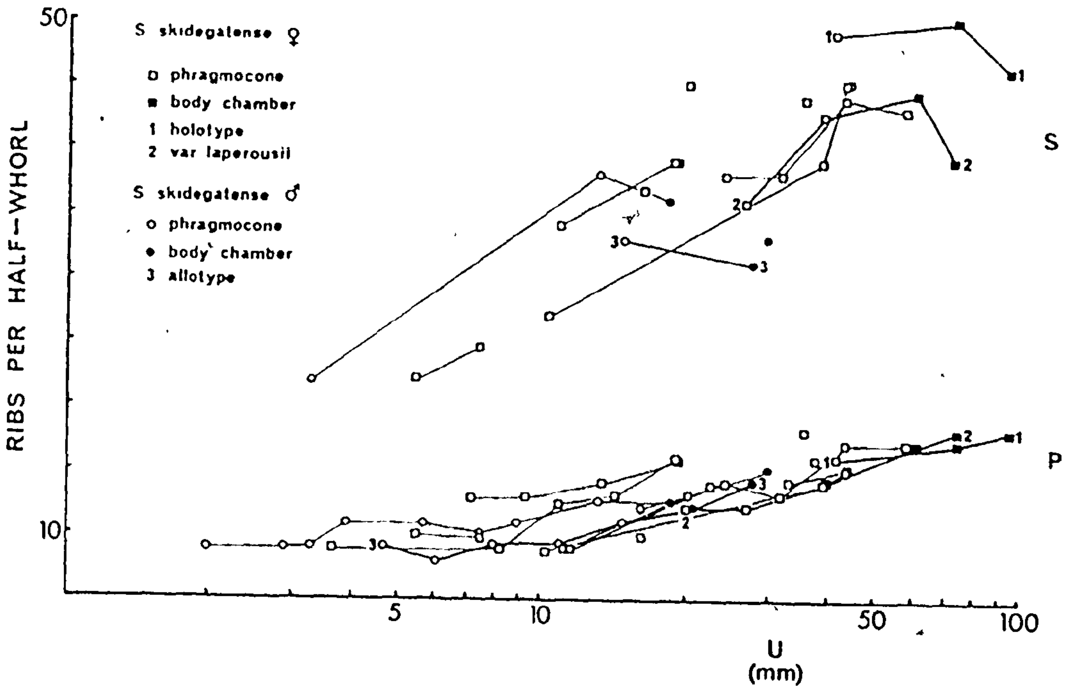
Stephanoceras skidegatense ♂

This dimorph has not been previously described.

Allotype: McM J1802a from Richardson Bay on the south shore of Maude Island, Skidegate Inlet, Queen Charlotte Islands (Text-fig. 1); approximately 20 m above the base of the Yakoun Formation exposed at this locality.

Material: In addition to the allotype, eight other microconchs (McM J1802b-g, 1805, 1803) were collected from the same locality, four of them complete with aperture.

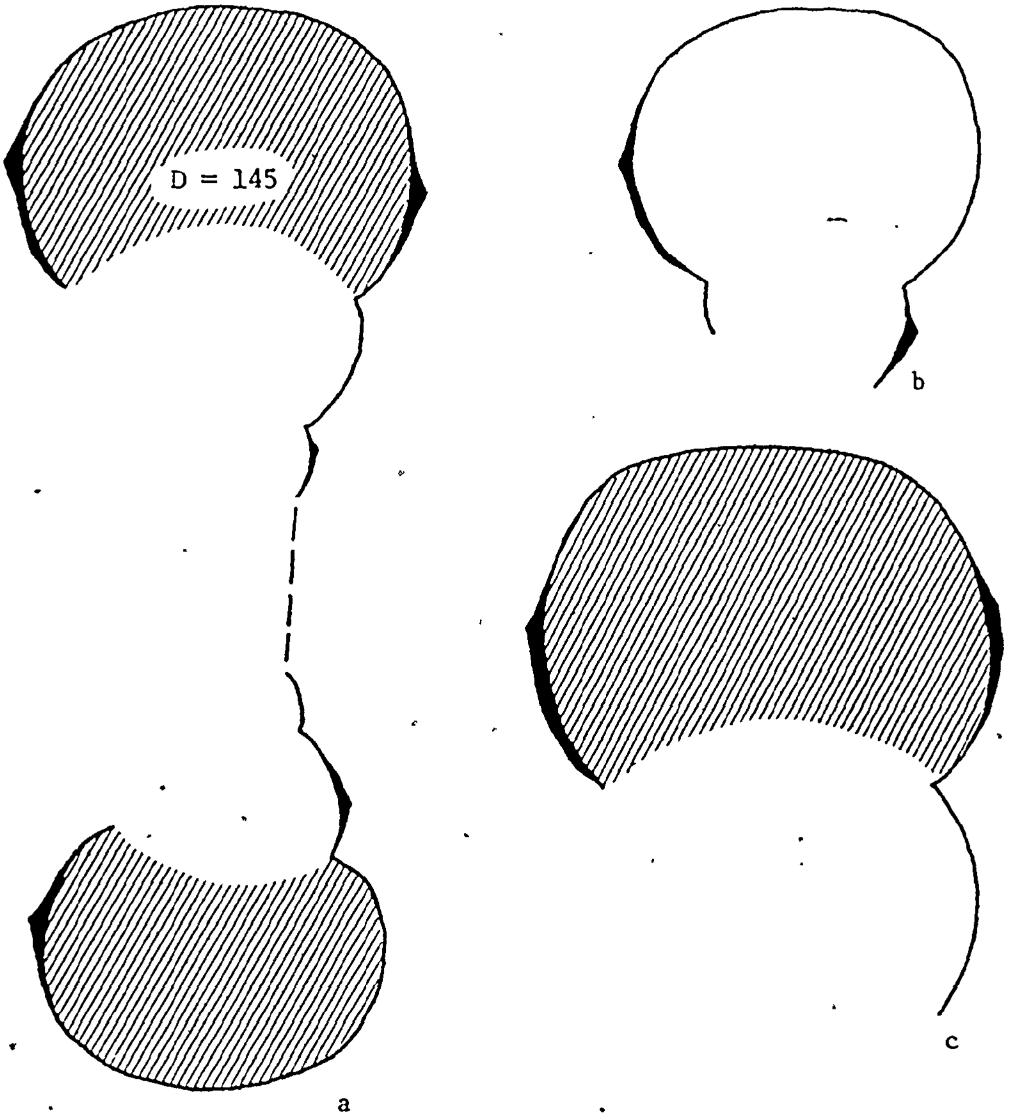
Description: This is the largest microconch stephanoceratid from any of



Text-fig. 37. Plot of the number of secondary (S) and primary (P) ribs per half-whorl against umbilical diameter (U) for *Stephanoceras skidegatense* (Whiteaves) ♀ & ♂ from Richardson Bay, Queen Charlotte Islands.

the Queen Charlotte Islands localities, attaining maximum diameters of 60-65 mm with robust ornamentation and only minor uncoiling on the last quarter-whorl.

At a diameter of 4 mm the whorl cross-section is coronate with a smooth shell, broadly arched venter, sharp lateral shoulder and slightly convex, moderately steep flanks. The only ornamentation at this stage consists of small, rounded tubercles situated on the lateral shoulder and extending adapicad as faint undulations about halfway down the flanks (incipient primary ribs). By a diameter of 6 mm faint secondary ribs appear, two to each primary, curving forward over the broad venter. Primary ribs are still seen only as faint extensions of the tubercles

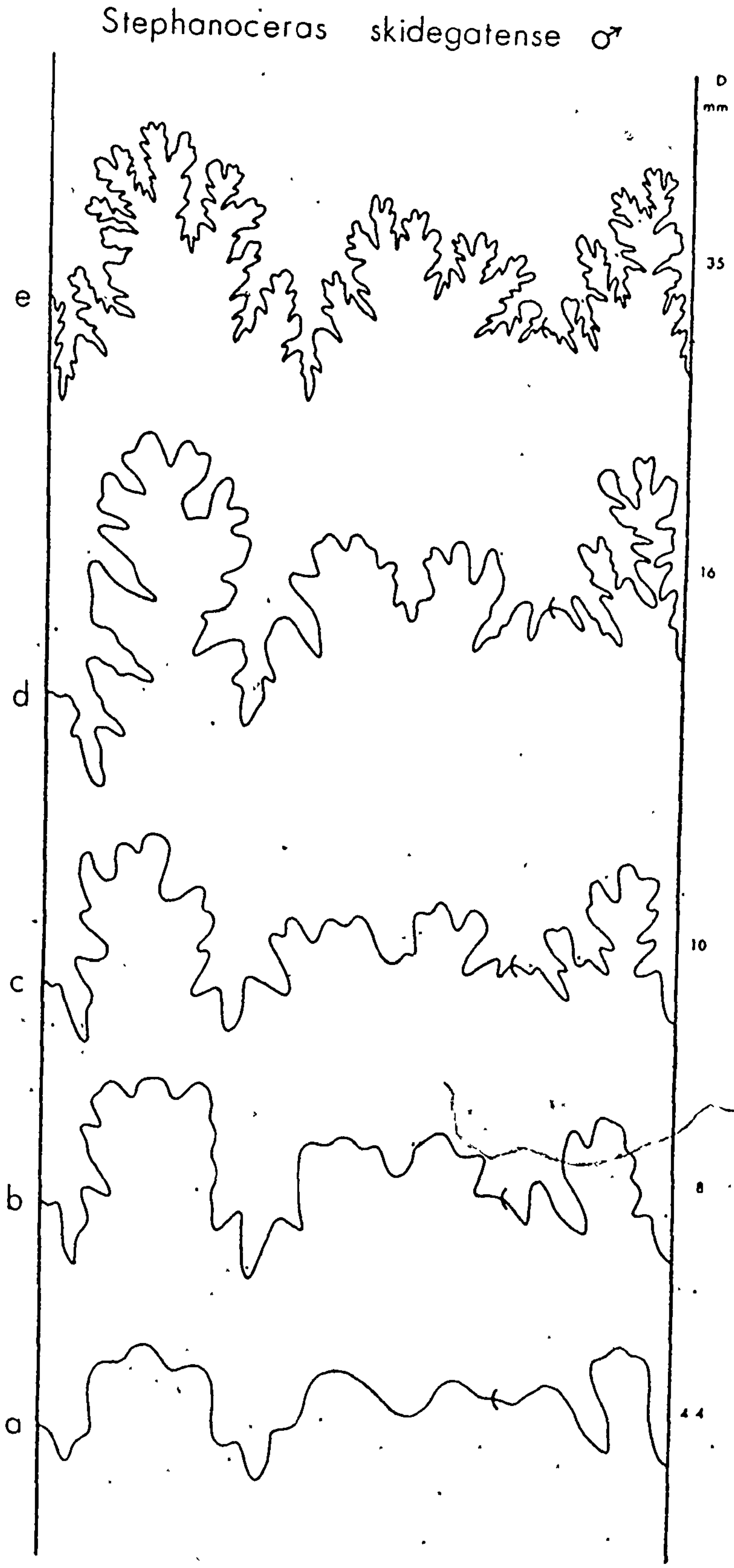


Text-fig. 38. Whorl cross-sections through the phragmocone and body chambers (shaded) for *Stephanoceras skidegatense* (Whiteaves) ♀. (a) *S. skidegatense* var. *laperousii* ♀ (holotype), GSC 6482, x 1; (b) *S. skidegatense* ♀ (holotype), GSC 5011, x 1; (c) *S. skidegatense* ♀, McM J1878, x 1.

onto the upper parts of the flanks. Earliest whorls very much wider than high with H/W ratios of 0.55-0.65.

Primary ribs become strong by D = 10 mm, extending right to the umbilical seam and curving forward with prominent, sharp tubercles on the lateral shoulder. Secondary ribs are broad and strong, curving forward from the tubercles then crossing straight over the venter. Throughout the remainder of the phragmocone the primary ribs are stronger than the secondaries, conspicuously curved, reaching maximum height in the middle of the flanks and terminating in prominent tubercles at 43-53% of the whorl height. The number of primary ribs increases gradually from 9 to 11 per half-whorl whilst the ratio of secondary to primary ribs increases from 2.5 to 3 by the end of the phragmocone. Whorl cross-section remains coronate with H/W ratios of 0.60-0.65, a broad venter and convex flanks (Text-fig. 40). There is no distinct umbilical wall.

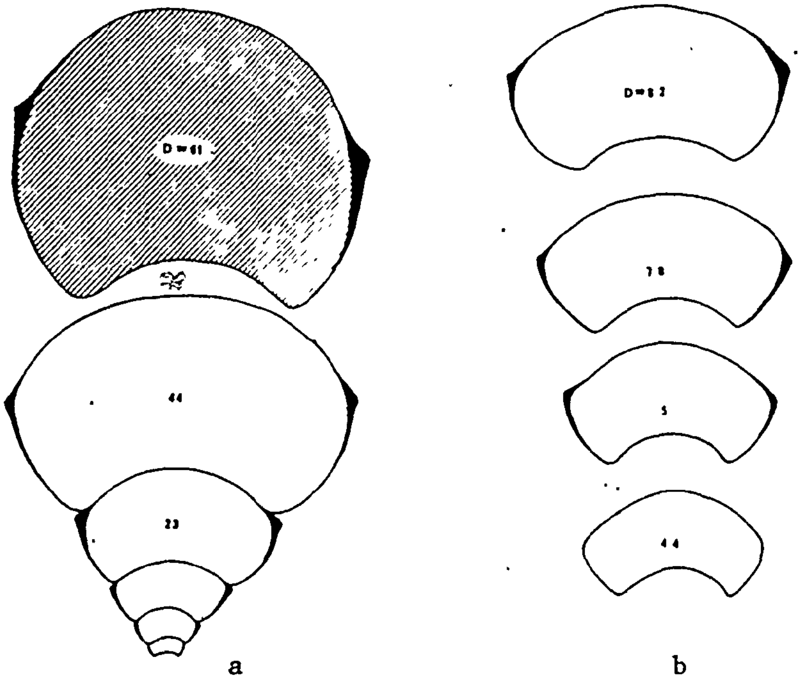
The body chamber is just over half a whorl in length, marked only by slight uncoiling of the last quarter-whorl. The whorl cross-section is oval and relatively higher than on the phragmocone whorls (H/W = 0.75-0.85). Both primary and secondary ribbing remains strong right to the aperture with 14-15 primaries on the last half-whorl but only 2-2.5 secondaries to each primary. The decline of secondary rib density is particularly noticeable on the last quarter-whorl where each primary rib bifurcates and intercalated ribs are absent. Tubercles become smaller, sharper and laterally elongated.



Text-fig. 39.

Sutural ontogeny for *Stephanoceras skidegatense* (Whiteaves) ♂.

a-e: McM J1802a



Text-fig. 40. Cross-section of the phragmocone and body chamber (shaded) of *Stephanoceras skidegatense* (Whiteaves) ♂. (a) McM J1802b, x 2; (b) McM J1802a, x 2.

There is no constriction preceding the aperture which is marked by a slightly flared lip; the beginning of the lateral lappets is visible on the four nearly complete specimens.

The mature suture is only moderately incised (Text-fig. 39). L is trifid and not as deep as E while U_2 is very short. U_3 is long, narrow and strongly oblique. E/L is higher than L/U_2; the tubercle is situated on the ventral side of the L/U_2 saddle.

Remarks: The decline to strong, bifurcating ribbing on the body chamber is similar to the body chamber ornamentation of *Zemistephanus* ♂. However, *S. skidegatense* ♂ reaches larger diameters, has less steep flanks, sharper ribbing, tubercles on the body chamber, more primary ribs on the last half-whorl (14-15 compared with 9-12 for *Zemistephanus* ♂) and a relatively higher whorl cross-section (H/W = 0.75-0.85 vs. 0.60-0.70).

S. itinsae (McLearn) ♂ differs strongly in having a higher density of secondary ribs on the body chamber (3 per primary) but fewer primary ribs per half-whorl (8-10 vs. 14-15).

S. skidegatense (Whiteaves) ♂ resembles *Normannites orbignyi* Buckman in coiling, whorl proportions and ornamentation. The holotype of *N. orbignyi* differs in rib density, having only 12 primaries on the last half-whorl; however, other specimens in the collections of the Geological Survey, London and the British Museum (Natural History) from Dorset show denser ribbing on the body chamber. The strong, curved primaries, sharp tubercles which decline on the body chamber and the strong, bifurcating secondary ribs all agree closely with the material here described as *S. skidegatense* (Whiteaves) ♂.

Dimorphism: The specimens described here for the first time as *S. skidegatense* ♂ are morphologically identical throughout the phragmocone whorls with the previously known macroconch specimens from Richardson Bay (Text-figs. 34-36). Whorl shape and dimensions, density and form of ribbing and changes in ornamentation during ontogeny are closely similar in both dimorphs. Body chamber modifications are also similar in both (excluding apertural modifications), which is unusual for the stephanoceratids described here.

Slight egression of the last part of the body chamber is accompanied by rounding of the whorl section, decrease in the density of secondary ribs (2-2.5 per primary) and changes in the nature of the tubercles. The persistence of strong secondary ribbing right to the aperture enables separation of this species from the closely-related *S. itinsae*.

Adult macroconch specimens are about 3 times the size of the largest microconchs (60–65 mm); in all collections so far made from the Richardson Bay locality they occur in approximately equal numbers.

Stephanoceras sp. ♂ aff. *S. skidegatense* (Whiteaves, 1876) ♂

(Pl. 8, figs. 2, 3; Text-fig. 41)

Material: Two partially preserved specimens from the lower part of the Yakoun Formation at Richardson Bay, Maude Island, Queen Charlotte Islands: McM J1804, half a body chamber whorl with a half-whorl of the preceding phragmocone attached, from 9 m above the base of the exposed section; and McM J1806, a smaller phragmocone found 20 m above the base of the section.

Description: The phragmocone whorls are depressed (H/W = 0.63-0.72) with a strongly arched venter which rounds evenly onto the inflated flanks, there being no lateral shoulder. The flanks slope gradually to the umbilical seam. Primary ribs are relatively short, reaching only 36-42%

Text-fig. 41. Cross-section through phragmocone and body chamber (shaded) whorl of *Stephanoceras* sp. ♂ aff. *S. skidegatense* (Whiteaves) ♂. McM J1804, x 1. From Richardson Bay.

of the whorl height where a rounded, elongate swelling is developed and bifurcation occurs. The primary ribs are strong, rounded and curved forwards; there are 9-12 per half-whorl. Secondary ribs are also strong, curving slightly forward from the point of bifurcation and then crossing straight over the venter; there are 26 per half-whorl (i.e. 2.4 to each primary).

The half-whorl of body chamber preserved shows gradual egression but the whorl section and ornamentation show little change. There are 14 primary ribs on the last half-whorl with 28 secondaries, all of which remain strong and rounded.

Remarks: This species is distinguished from *S. skidegatense* (Whiteaves) ♂ by its stronger, more widely spaced secondary ribbing on the phragmocone whorls (compare Pl. 8, figs. 1b, c with Pl. 8, figs. 2b, 3a), more rounded whorl cross-section with highly arched venter but lacking a lateral shoulder and shorter, thicker primary ribs without sharp tubercles.

S. itinsae (McLearn) ♂ differs in the higher density of secondary ribbing which persists almost to the aperture and the more coronate whorl section with a clearly defined lateral shoulder and broad venter on the phragmocone whorls.

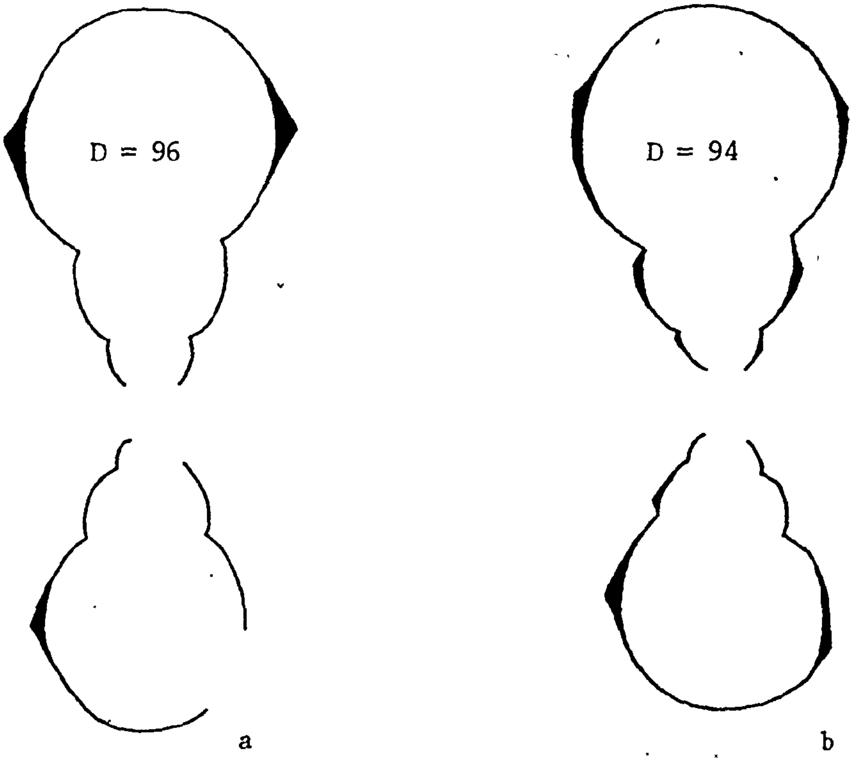
Stephanoceras sp. aff. *S. caamanoi* McLearn, 1930 ♀

(Pl. 10, fig. 1; Text-fig. 42a)

Material: McM J1779k, from Agua Dulce, Caracoles, Antofagasta Province, Chile; upper part of the "*Stephanoceras* beds". The specimen reaches a maximum diameter of 93 mm and is entirely septate.

Description: Whorl cross-section rounded, lacking lateral shoulder, and almost as wide as high with H/W = 0.85-0.95 (Text-fig. 42a). The strongly arched venter rounds gradually onto the flattened flanks which in turn curve a little more strongly toward the umbilical seam. The umbilicus is broad (U/D = 0.4) and shallow. Slow egression of the umbilical seam from the line of tubercles commences well before the end of the phragmocone at U = 20 mm.

Ornamentation is strong but not sharp. Primary ribs curve forward strongly, their number increasing during ontogeny from 14 to 18 per half-whorl. Rounded tubercles are situated at, or just above, the mid-height of the whorl. Secondary ribs pass straight across the venter, with 3-4 per primary.



Text-fig. 42. (a) Cross-section of phragmocone whorls of *Stephanoceras* sp. aff. *S. caamanoi* McLearn ♀ ; McM J1779k, from Caracoles, Chile, x 1; (b) Cross-section of phragmocone whorls of *Stephanoceras caamanoi* McLearn, 1930 ♀ ; GSC 9056 (holotype), from South Balch Island, Queen Charlotte Islands, x 1.

Remarks: In whorl shape, coiling and the long primary ribs this specimen closely resembles *S. caamanoi* McLearn; however, the latter has slightly denser primary ribbing (20 vs. 18 per half-whorl at D = 87 mm). While on *S. caamanoi* the number of primary ribs per half-whorl increases during ontogeny from 12 to 21, on the present specimen the innermost whorls show fine, dense ribbing (14-18 per half-whorl) which becomes coarser on later whorls (12 per half-whorl) before finally increasing in density on the outer phragmocone whorls. Secondary ribs on *S. caamanoi* are coarser.

Stephanoceras humphriesianum (Sowerby) has slightly fewer, shorter and straighter primary ribs (16 vs. 18 per half-whorl at a similar diameter) which terminate in rounded tubercles at only one-third of the whorl height, whereas those on the present specimen extend to one-half of the whorl height. The inner whorls of *Stephanoceras kirschneri* Imlay are relatively narrower and higher (H/W of 0.98 vs. 0.91) and have shorter primary ribs which are less densely spaced, there being only 10-15 per half-whorl.

The fully septate holotype of *Stephanoceras caamanoi* McLearn, 1930 ♀ clearly differs from *S. itinsae* (McLearn, 1927) ♀ from the same locality in the compressed whorl section and highly arched venter (compare Text-fig. 42b with Text-fig. 30). Egression of the umbilical seam occurs at a much earlier stage on *S. caamanoi* ♀ (U = 26 mm vs. 45-50 mm).

Stephanoceras sp. aff. *S. kirschneri* (Imlay), 1964 ♀

(Pl. 9, fig. 1; Pl. 10, fig. 2; Text-fig. 43)

Material: GA 1035a, a large, well-preserved phragmocone with part of what is probably badly crushed body chamber attached, and GA 1035b, about one quarter-whorl of phragmocone; both from the collection of Mr F. Garcia, E. N. A. P. (Inst. Geol., Univ. Nac., Santiago) from Salar de Pedernales, Atacama Province, Chile. Specimens referred to in Westermann and Riccardi, 1972a, p. 20.

Text-fig. 43. Cross-section of phragmocone whorls of *Stephanoceras* sp. aff. *S. kirschneri* Imlay ♀ ; GA 1035a, from Salar de Pedernales, Chile, x·1.

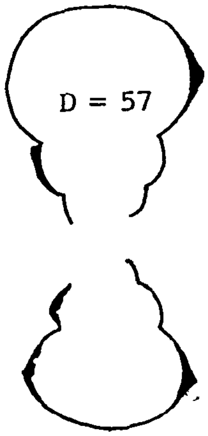
Description: Coiling becomes serpenticone at an early stage with egression of the umbilical seam from the line of tubercles at U = 21 mm. Whorl section oval, slightly wider than high (H/W of 0.90 at D = 88 mm) with gently rounded flanks curving smoothly onto the highly arched venter (Text-fig. 43). Umbilical wall short, curved and moderately steep; umbilicus occupies about 40% of shell diameter. Maximum width of the whorls occurs at about one-third of the whorl height.

Primary ribs of moderate strength, curved forward, rounded rather than sharp, ending in large, round tubercles at about one-third of the whorl height. On the attached (?)body chamber fragment primary ribs are weak but the large, round tubercles persist, low on the flanks. Secondary ribs curve slightly forward from the tubercle then cross straight over the venter; on the phragmocone they are of medium strength and closely spaced with 3 to each primary rib, while on the (?)body chamber this ratio increases to 4 or more and the secondary ribs have greater relief than the primaries. Primary ribs are closely spaced, increasing from 10-11 per half-whorl at U = 5-12 mm to 15 at U = 30 mm.

Remarks: These specimens agree very closely with the described and figured specimens of *S. (Skirroceras) kirschneri* Imlay from southern Alaska which is here trasnferred to *Stephanoceras* s.s. because of its strong similarity with the type species, *Stephanoceras humphriesianum* (Sowerby) (see discussion, p. 157). *S. kirschneri* has relatively higher whorls on the inner phragmocone than the present specimens (H/W of 0.98 vs. 0.90 at D = 88 mm). In whorl dimensions these specimens also agree closely with *S. caamanoi* McLearn from the Queen Charlotte Islands, but in style and density of rib ing they are closer to *S. kirschneri*. Primary ribs on *S. caamanoi* are longer (extending to half the whorl height), more closely spaced (21 vs. 15 per half-whorl) and more strongly curved, but terminate in smaller tubercles.

Stephanoceras n. sp. juv.

(Pl. 9, fig. 4; Text-fig. 44)



Text-fig. 44. Cross-section of phragmocone whorls of *Stephanoceras* n. sp. juv., GA 1035c from Salar de Pedernales, Chile; x 1.

<u>Material</u>: A single phragmocone specimen, GA 1035c in the collection of Mr F. Garcia E. N. A. P. (Inst. Geol., Univ. Nac., Santiago) from Salar de Pedernales, Atacama Province, Chile (specimen referred to in Westermann and Riccardi, 1972a, p. 20).

<u>Description</u>: At the end of the preserved specimen (D = 60 mm) uncoiling has begun with egression of the umbilical seam from the tubercles on the previous whorl. Whorls depressed, oval in cross-section (H/W = 0.70) with inflated flanks and gently arched venter (Text-fig. 44), lacking any lateral shoulder. Primary ribs only slightly curved forward, long and fine, reaching to half the whorl height on the outermost preserved whorl, probably relatively longer on inner whorls. Large, rounded tubercles situated at maximum whorl width, 11-13 per half-whorl. Secondary ribs fine, densely spaced and outnumbering primary ribs 4:1; cross straight over the venter.

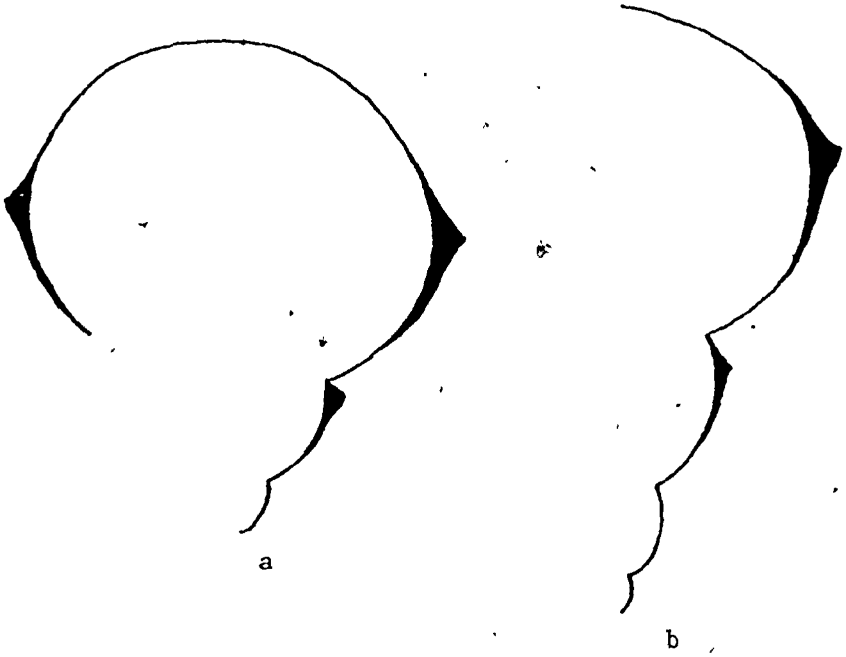
Remarks: The style of ornamentation on this specimen closely resembles that on the inner whorls of *S.* cf. *kirschneri* ♀ (Pl. 9, fig. 1) from the same locality. However, that specimen has shorter primary ribs and a more compressed whorl section (H/W = 0.90) with a narrower, more strongly arched venter. *S.* cf. *caamanoi* ♀ from Caracoles (Pl. 10, fig. 1) also has a more compressed whorl section (H/W = 0.85-0.95) with denser, more strongly curved primary ribbing. *S. (Skirroceras)* cf. *macrum* from Chacaico, Neuquén Province, Argentina (Pl. 9, fig. 3) also has more compressed whorls on the phragmocone with sharper and more prominent tubercles.

Stephanoceras n. sp. indet. ♀

(Pl. 10, fig. 3; Pl. 11, fig. 1; Text-fig. 45)

Material: McM J1779b, a large phragmocone specimen with only a half-whorl preserved and parts of several successive inner whorls, from the upper part of the "*Stephanoceras* beds", Agua Dulce, Caracoles, Antofagasta Province, Chile; McM J1777b, half a phragmocone whorl with parts of several inner whorls attached, silicified, from Caracoles.

Description: Whorls with inflated flanks and broad, arched venter, depressed (H/W = 0.65-0.75). Flanks curve continuously to the umbilical seam with no distinguishable lateral shoulder or umbilical wall (Text-fig. 45). Umbilicus deep, representing 40% of shell diameter; umbilical seam lies along the line of tubercles on the previous whorl and neither



Text-fig. 45. Whorl cross-sections through phragmocone whorls of *Stephanoceras* n. sp. indet ♀ . (a) McM J1777b, from Caracoles, Chile; x 1; (b) McM J1779b, from Caracoles, Chile; x 1.

specimen shows egression. Features of the body chamber and aperture unknown.

Primary ribs long (extending 50-70% of the whorl height), thin, sharp and strongly curved forward, especially on inner whorls; closely spaced with 12-14 per half-whorl. Tubercles conical and sharp, situated high on the flanks. Secondary ribs much finer and more numerous, outnumbering the primary ribs 5-6:1, and crossing straight over the venter.

Umbilical lobes of the external suture are strongly oblique.

Remarks: These specimens differ from previously described broad-whorled species of *Stephanoceras* s. s. in having long, sharp and curved primary ribs and dense, fine secondaries. In both these features they are similar to species of *Cadomites* but are distinguished from members of that genus in having strongly oblique umbilical lobes in the suture (Westermann, 1956b; Westermann and Rioult, 1975).

Subgenus *Stephanoceras (Skirroceras)* Mascke, 1907

Type Species: *Skirroceras macrum* (Quenstedt, 1886/7), by original designation.

Remarks: European representatives of this Subgenus are many-whorled, serpenticone forms with a wide, shallow umbilicus. Egression of the umbilical seam from the line of tubercles on the previous whorl occurs at umbilical diameters less than 40 mm and always well before commencement of the adult body chamber. Whorls are circular in cross-section early in ontogeny with H/W ratios exceeding 0.90 at diameters of 140 mm and increasing to greater than 1.0 on the body chamber.

Three species of *Stephanoceras (Skirroceras)* have been described from southern Alaska: *S. juhlei*, *S. nelchinanum* and *S. kirschneri* Imlay spp. (Imlay, 1964, pp. 46-48). Of these, *S. kirschneri* is said to resemble closely the European *S. macrum* (Quenstedt) in all features except the mature body chamber which on the Alaskan species is relatively higher. Inner whorls of *S. (Skirroceras) kirschneri* (Imlay, 1964; Pl. 18, figs. 1-3; Pl. 19, figs. 3, 5, 6) are very similar to the fully septate lectotype of *Stephanoceras humphriesianum* (Sowerby) in whorl shape, coiling and ribbing. The primary ribs on *S. (Skirroceras) kirschneri* are a little more widely spaced (at D = 102 mm, 16 vs. 18 per half-whorl) while the density of secondary ribs is a little higher (4.5 per primary vs. 3.0).

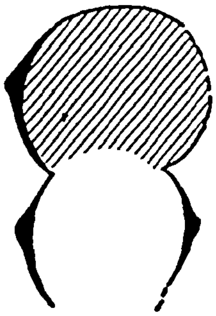
None of the Alaskan species placed in the Subgenus *Skirroceras* has the circular whorl section and sharp ornamentation characteristic of *Skirroceras macrum* and so they are here transferred to *Stephanoceras* s. s. The Subgenus *S. (Skirroceras)* is retained only for those forms closely resembling *S. (Skirroceras) macrum* with circular whorl sections and sharp ornamentation of high relief.

Stephanoceras (Skirroceras) cf. *macrum* (Quenstedt, 1886/7)

(Pl. 9, fig. 3; Text-fig. 46)

Material: McM J1323a, from the Lajas Formation, Chacaico, Neuquén Province, Argentina. Short segments of two successive whorls, partly corroded; specimen referred to by Westermann and Riccardi (1972a, p. 10).

Description: Outer whorl fragment (possibly body chamber) rounded in cross-section, almost as high as wide (H/W = 0.92), with inflated flanks and strongly arched venter (Text-fig. 46). Coiling at this stage evolute



Text-fig. 46. Cross-section of phragmocone and probable body chamber whorl of *S. (Skirroceras)* cf. *macrum* (Quenstedt). McM J1323a from Lajas Formation, Chacaico, Argentina, x 1.

with little whorl overlap and secondary ribbing on inner whorl well exposed. Ornamentation strong with short, almost straight primary ribs terminating in large, conical tubercles at half the whorl height. Secondary ribs strong, four to each primary, directed forward from the tubercles, then crossing straight over the venter.

Remarks: This specimen occurs with *Emileia* sp. ♀ , *Sonninia (S.?)* cf. *alsatica* ♀ & ♂? (Haug) and *S. (Papilliceras)* cf. *espinazitensis* ♀ (Westermann and Riccardi, 1972a, p. 10) indicating the Sauzei Zone. It closely resembles *Skirroceras macrum* in the evolute coiling, round whorl section and short primary ribs with tubercles at about half the whorl height and the dense, sharp secondary ribbing.

Subgenus *Stephanoceras (Stemmatoceras)* Mascke, 1907

Type Species: *Stemmatoceras coronatum* (Quenstedt, 1886/7) [= *S. frechi* Renz, 1913] by original designation.

Remarks: Six species have been assigned to *Stemmatoceras* from widely scattered localities in western North America:

Stemmatoceras albertense McLearn, 1928; base of the Fernie Group, headwaters of Sheep Creek, Alberta;

Stemmatoceras palliseri McLearn, 1930; Fernie Group, upper Whitehorse River, Mountain Park area, Alberta;

Stemmatoceras mclearni Warren, 1947; specimen as float in Miners Creek near Cadomin, Alberta (presumed to be from the Rock Creek Member, Fernie Group);

Stemmatoceras carri Warren, 1947; Rock Creek Member, Fernie Group near Cadomin on the Whitehorse River and near Burns Mine, south-west of Calgary (three syntypes);

Stemmatoceras ursinum Imlay, 1964; Fitz Creek Siltstone, southern Alaska, and,

Stemmatoceras arcicostum Imlay, 1967; Sliderock Member, Twin Creek Limestone, Montana.

Measurements of whorl dimensions and ribbing densities for the four Canadian species have been compared with data for a number of species of *Stephanoceras* s.s. from western Canada and Europe. Data for the Canadian species include measurements on plastotypes, additional material collected from the Rock Creek Member in Ribbon Creek, southern Alberta and on material loaned by the University of Alberta, as well as the original published holotype measurements. All the western Canadian *"Stemmatoceras"* have whorl dimensions corresponding closely with those of *Stephanoceras* s. s. spp. (in particular *S. itinsae* (McLearn) ♀ and *S. skidegatense* (Whiteaves) ♀).

"Stemmatoceras" albertense McLearn has as holotype a fully septate, distorted specimen on which only one side is preserved; most of the ventral parts of the ultimate whorl have been crushed. In whorl dimensions and the long, curved primary ribs (18-20 per half-whorl) this specimen closely resembles *Stephanoceras itinsae* (McLearn) ♀. It does not have narrower whorls or a shallower umbilicus than *"Stemmatoceras" palliseri* McLearn as suggested by Warren (1947, p. 68) but differs in having more primary ribs (18 vs. 13 per half-whorl at similar diameters). The relatively undistorted specimen from Ribbon Creek described and figured by Frebold (1957, p. 50; Pl. XXI, figs. 2a, b; Pl. XXIII, figs. 1a-c) as *Stemmatoceras albertense* McLearn is identical with *Stephanoceras itinsae* (McLearn) ♀ from the Queen Charlotte Islands. The inner whorls as measured by Frebold (p. 51) correspond in all dimensions with *S. itinsae* and the increase in whorl height on the last preserved whorl and fine, dense secondary ribbing strongly confirm identification with that species.

The holotype of *"Stemmatoceras" palliseri* McLearn is a wholly septate specimen, somewhat distorted and corroded. The whorls are cadicone with a highly arched venter, moderately steep and curved lower flanks and a moderately deep umbilicus. It differs from *S. itinsae* only in the nature of the primary ribs which are shorter, broader and more widely spaced (14 per half-whorl at D = 130 mm). *"Stemmatoceras"* cf. *"S." palliseri* McLearn described by Imlay from southern Alaska (1964, pp. B48, 49; Pl. 20, figs. 5, 6; Pl. 21, figs. 2, 4) also has whorl dimensions and coiling very similar to *S. itinsae* with a corresponding decline in ornament on the body chamber. However, the Alaskan specimen has fewer primary ribs (12 vs. 16-19 per half-whorl at D = 130 mm) with larger nodes. Secondary ribs are rather more dense on the inner whorls of Imlay's specimen but become broader and less dense (3 secondaries per primary) on the body chamber (as on *S. itinsae*).

"Stemmatoceras" mclearni Warren has an almost entirely septate holotype with egression of the umbilical seam just beginning near the end of the specimen. The umbilicus is broad and shallow with slightly inflated flanks rounding gently onto the venter. On the internal mold the ribs are only of moderate relief, long and curved with small, round tubercles. On the greater part of the ultimate whorl the venter has been badly crushed and corroded but the secondary ribs are of moderate relief curving very slightly forward from the tubercles, with about three to each primary at the beginning of the body chamber. This species bears a very close resemblance to *Stephanoceras itinsae* (McLearn) ♀, differing only in having a shallower umbilicus and slightly less dense

primary ribbing.

"Stemmatoceras" carri Warren was based on three syntypes which are characterised by early flattening of the flanks and increased arching of the venter (Warren, 1947, p. 69). The long, curved primary ribs are less robust than those of *"Stemmatoceras" mclearni* and more closely spaced; the flanks of *"S." carri* are steeper and more inflated, at least on the early whorls. The syntype from the headwaters of Sheep Creek near Burns Mine (UA Jr 485) is an incomplete phragmocone reaching only 80 mm diameter. In whorl dimensions it is very close to the inner whorls of *Stephanoceras itinsae* (McLearn) ♀ and has similar ornamentation: long, curved primary ribs (16 per half-whorl at D = 80 mm) terminating in small, sharp tubercles and with 3-4 fine secondary ribs per primary.

The coronate inner whorls with broad primary ribs and large, conical nodes along a well-defined lateral shoulder and the marked egression and rounding of the body chamber on *"Stemmatoceras" ursinum* Imlay are all features strongly reminiscent of *Zemistephanus* spp. (especially Z. *alaskensis* n. sp. ♀).

The large size and rounded final whorl of *"Stemmatoceras" arcicostum* Imlay are features in common with the supposed *"Teloceras" allani* Warren; however, the latter has longer, more closely spaced primary ribs with stronger, less dense secondaries. The inner whorls on both forms remain poorly known.

PREVIOUS TAXA	HERE
Stemmatoceras albertense McLearn (holotype)	*Stephanoceras albertense* (McLearn) ♀
Stemmatoceras albertense McLearn; Frebold, 1957	*Stephanoceras itinsae* (McLearn) ♀
Stemmatoceras palliseri McLearn (holotype)	*Stephanoceras palliseri* (McLearn) ♀
Stemmatoceras cf. *S. palliseri* McLearn; Imlay, 1964	*Stephanoceras* cf. *S. palliseri* (McLearn) ♀
Stemmatoceras mclearni Warren (holotype)	*Stephanoceras itinsae* (McLearn) ♀
Stemmatoceras carri Warren (holotype)	*Stephanoceras itinsae* (McLearn) ♀
Stemmatoceras ursinum Imlay (holotype)	? *Zemistephanus* sp. ♀
Stemmatoceras arcicostum Imlay (holotype)	?

Table 8. Suggested taxonomic placement of material from western North America previously identified with *"Stemmatoceras"*.

All the specimens from western Canada assigned to *"Stemmatoceras"* increase in whorl height during ontogeny with arching of the venter and a change from cadicone to serpenticone coiling. This is particularly noticeable on the body chambers where umbilical enlargement is also seen, along with a decline in the strength and density of ribbing. All of these ontogenetic changes find parallels in *Stephanoceras itinsae* ♀ and *S. skidegatense* ♀. It does not appear reasonable to maintain separation of these four Canadian species in the subgenus *"Stemmatoceras"* recognition of which is largely based on greater relative whorl width. The inner whorls of Canadian *Stephanoceras* s. s. and *"Stemmatoceras"* are coronate till quite late in ontogeny with uncoiling and contraction of the whorl to an oval or rounded cross-section occurring only on the last whorl (and corresponding closely to the beginning of the body chamber). I believe that these species of *"Stemmatoceras"* ought to be transferred to *Stephanoceras* s. s. and that some (*S. carri* and *S. mclearni*) are actually synonymous with *S. itinsae* ♀. Table 8 lists the taxonomic treatment suggested here for ammonites from western North America previously identified as *"Stemmatoceras"*.

Genus *Teloceras* Mascke, 1907

Type Species: *Teloceras blagdeni* (J. Sowerby, 1818), by original designation.

Remarks: *Teloceras* Mascke was originally distinguished from other stephanoceratids by its strong nodes, sharp umbilical shoulder and the great thickness of the whorls (Mascke, 1907, p. 31). The distinctiveness of this genus was further emphasised by Weisert (1932) and Schmidtill and Krumbeck (1938). They indicated that, although the complete body chamber was rarely seen, the mature shell exhibited a decline in the strength of the sculpture, slight rounding of the whorl section and, in some forms, minor egression. A number of almost complete specimens was examined by me in the British Museum of Natural History. At least the adapical parts of the body chamber remain strongly coronate in whorl section with broad whorls and flat venter and large, round nodes situated along the acute lateral shoulder. In many the venter is almost smooth due to the loss of secondary ribbing.

The following species have been ascribed to this genus from western North America:

Teloceras dowlingi McLearn, 1930, p. 2. Fully described and figured by McLearn, 1932, p. 112; Pl. 1; Pl. 5, figs. 2, 3. Rock

Creek Member at ?Ribbon Creek, southern Alberta. Holotype GSC 9050.

Teloceras warreni McLearn, 1930, p. 3; Pl. 1, fig. 4; and McLearn, 1932, p. 113; Pl. 3; Pl. 4. Fernie Group, Porcupine Creek, Kananaskis River, southern Alberta. Holotype UA Jr 114.

Teloceras itinsae McLearn, 1932, p. 51; Pl. 10, figs. 1, 2. Talus in the lower Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. Holotype GSC 6481.

Teloceras stelcki Warren, 1947, p. 71; Pl. VI, fig. 1. Rock Creek Member, Fernie Group, Whitehorse River near Cadomin, Alberta. Holotype UA Jr 490.

Teloceras allani Warren, 1947, p. 70; Pl. II, fig. 1. Rock Creek Member, Fernie Group, Highwood-Sheep River area, Alberta. Holotype UA Jr 479.

Teloceras dowlingi McLearn is based on an incomplete specimen which is wholly septate except for about one quarter-whorl of body chamber. In his first full description of this species McLearn (1932, pp. 111-113) himself noted some important deviations from the established characters of *Teloceras* Mascke. Most of these differences are apparent on the body chamber: egression of the umbilical seam from the line of nodes, high arching of the venter and rounding of the previously steep umbilical walls, and a marked decrease in the strength of the nodes. On the body chamber H/W increases to 0.71 which is far greater than any known values for undoubted species of *Teloceras* from western Europe (values of 0.40-0.50 are common at similar growth stages).

The holotype of *Teloceras warreni* McLearn, judging from McLearn's illustration (1932, Pl. 3; Pl. 4), is almost entirely septate with a short and very steep umbilical wall, an acute shoulder with round, blunt nodes and even at early stages a highly arched and rounded venter. The umbilicus is narrow (less than 50% of the total diameter) and deep, even after gradual uncoiling commences about one whorl before the end of the specimen. McLearn (1932, p. 113) also noted the similarities of the inner whorls of this specimen to *Zemistephanus vancouveri* [= *Z. richardsoni* ♀] from the lower Yakoun Formation, Queen Charlotte Islands. The deep, crater-like umbilicus, narrow and steep umbilical wall and large, round nodes low on the flanks certainly indicate a close relationship with *Zemistephanus*; however, the specimen in question is considerably larger than most *Zemistephanus* ♀, except *Z. alaskensis* n. sp. from southern Alaska (p. 107). Strong elliptical uncoiling of the umbilical seam in *Zemistephanus* begins only at the end of the phragmocone (over the last half-whorl before the aperture).

Teloceras itinsae McLearn was based on a small (D = 71 mm) septate specimen with features similar to *Teloceras*; several additional phragmocone specimens have been collected by the writer from the type locality, all as float. The nature of the mature whorls and body chamber remain unknown. Coiling is involute with the umbilical seam running along the line of nodes; the latter are prominent and situated on the acute lateral shoulder which separates the steep umbilical walls from the broad, gently arched venter. At this growth stage there is a close similarity with the inner whorls of *T. dowlingi* McLearn in all features except the strength and density of the secondary ribbing (*T. dowlingi* has 4 secondary ribs per primary vs. 3 on *T. itinsae* at similar diameters). Twenty-eight specimens (of which three were figured) from southern Alaska have been placed in this species (Imlay, 1964, pp. B50, 51). He notes that the body chamber of several large, complete specimens becomes nearly as high as wide and uncoils over the last half-whorl; the aperture is simple. While the umbilicus is deep and narrow on the inner whorls, with large, round nodes on the lateral shoulder (similar to *Teloceras*), the venter is rather more strongly arched and the lateral shoulder less abrupt. On the body chamber the umbilical wall becomes progressively less steep till near the aperture it grades continuously onto the highly arched venter. The loss of the steep umbilical wall and the relatively narrow body chamber (H/W = 0.65-0.90) with highly arched venter all clearly distinguish these Alaskan specimens from any known *Teloceras*. They compare closely with *Zemistephanus* McLearn ♀ from the Queen Charlotte Islands and southern Alaska in possessing a deep umbilicus with steep walls, large blunt nodes along the lateral shoulder, increased arching of the venter on the adult whorls and marked egression of the body chamber. These specimens are here regarded as a new species of *Zemistephanus*, *Z. alaskensis* n. sp. ♀ (p. 107).

Teloceras stelcki Warren also shows body chamber features atypical for *Teloceras*: egression, arching of the venter and increased whorl height (H/W = 0.70-0.90) according to Warren's original measurements (Warren, 1947, p. 71).

The holotype of *Teloceras allani* Warren is by far the largest of this group (D = 277 mm) and has almost one whorl of body chamber preserved. The inner whorls are tightly coiled with the umbilical seam following the line of nodes; these are small, round and situated on the lateral shoulder. Umbilical walls are steep producing a deep and narrow umbilicus. Uncoiling commences about half a whorl before the end of the phragmocone. At the same time the umbilical walls become rounded and less steep, merging more gradually with the arched venter (H/W increases from 0.64 to 0.84). The strong primary ribs which, on the inner whorls, are conspicuously directed forward as they approach the umbilical seam, become broader and decline in strength on the body chamber till near the end they are quite faint; nodes and secondary ribs also decline on the body chamber. Again, the characteristics of this specimen clearly separate it from *Teloceras*.

These forms from western North America with cadiconic early whorls of *Teloceras*-aspect which on the body chamber undergo uncoiling, marked increase in relative whorl height and arching of the venter might best be grouped as a subgenus of *Teloceras*. This group would initially include *T. dowlingi, T. allani* and *T. stelcki; T. itinsae* may be included but the body chamber characteristics are unknown.

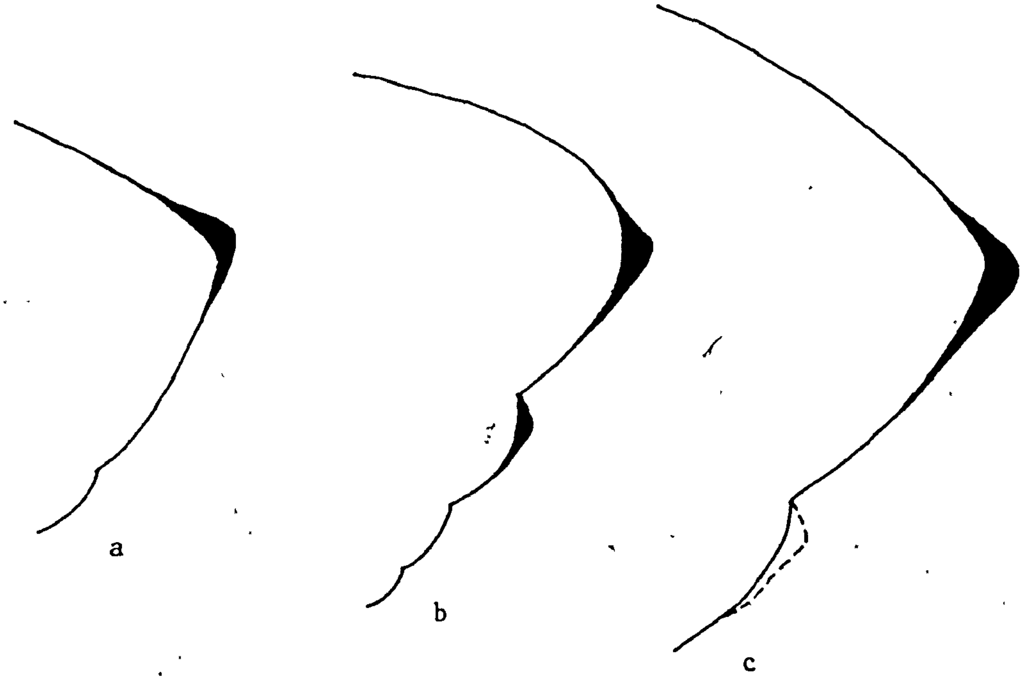
Possibly the only true *Teloceras* yet described from North America is a specimen from the Rock Creek Member in Ribbon Creek, southern Alberta figured by Frebold (1957, pp. 52, 53; Pl. XXV, fig. 1; Pl. XXVI, fig. 1; Pl. XXVII, fig. 1) and identified as *Zemistephanus crickmayi*.

According to Frebold's description this fully septate fragment is characterised by a deep, conical umbilicus, extremely thick and low cross-section, broad and only slightly arched venter and high, conical tubercles. Primary ribs are not strongly developed but from the tubercles situated on the acute lateral shoulder relatively fine secondary ribs cross almost straight over the venter. There are about four secondary ribs to each tubercle at a diameter of 97 mm; on the fragment of the next outer whorl this number is the same. At U = 50 mm there are 11 tubercles per half-whorl. From the acute lateral shoulder straight umbilical walls descend very steeply to the seam. Though there is slight egression of the last preserved whorl fragment from the line of tubercles there is no decline in the steepness of the umbilical wall, nor increased rounding of the whorl section, as usually found in *Zemistephanus*. On the last whorl H/W = 0.50; on the next inner whorl it is 0.53. The spacing of tubercles and secondary ribs, and the whorl shape, are very similar to those on *T. blagdeni* (Sowerby). Several other fragments in the McMaster collections from the Ribbon Creek locality of the Rock Creek Member (McM J1200) also belong to *Teloceras*.

Teloceras sp. aff. *T. multinodum* (Quenstedt, 1886) ♀

(Text-fig. 47a, c)

Material: McM J1777a, J1779a from Caracoles, Antofagasta Province, Chile. Both specimens consist of about a quarter of a large, septate whorl with parts of several inner whorls attached; only one side of the whorls is preserved.



Text-fig. 47. Cross-sections through phragmocone whorls of fragments of *Teloceras*. (a) *Teloceras* sp. aff. *T. multinodum* (Quenstedt); McM J1779a, x 1; from Caracoles, Chile; (b) ?*Teloceras* sp. indet.; McM J1295, x 1; from Caracoles, Chile; (c) *Teloceras* sp. aff. *T. multinodum* (Quenstedt); McM J1777a, x 1; from Caracoles, Chile.

Description: Whorls strongly coronate with broad, almost flat venter. The transition to the flanks is marked by a sharp lateral shoulder lined with pointed, conical nodes. Flanks not inflated and falling straight to the umbilical seam.

On the inner whorls of McM J1779a there are 10 primary ribs per half-whorl; they are strong, but not sharp, and curve forward approaching the umbilical seam. On the later whorl primary ribs are broad on the upper flanks but disappear on the lower flanks which are almost smooth, being marked only by growth lines. Secondary ribbing is visible only on McM J1777a where there are four to each primary. The sharp nodes are situated along the lateral shoulder which is the point of maximum whorl width (at about 75% of the whorl height). The only exposed part of the suture shows strongly oblique umbilical lobes.

Remarks: Another large and well preserved specimen from Chacay Melehue, Neuquén Province, Argentina (McM J1757) is also compared with *Teloceras multinodum* (Quenstedt) by Westermann and Riccardi (1972a, p. 13). The phragmocone whorls are very similar to those of the specimens described here.

?*Teloceras* sp. indet.

(Pl. 11, fig. 3; Text-fig. 47b)

Material: McM J1295, from Caracoles, Antofagasta Province, Chile. Parts of three successive whorls preserved with one side corroded.

Description: Whorls coronate with broadly arched venter, rounded lateral shoulder and steep flanks falling to the umbilical seam. Whorls strongly depressed with H/W = 0.56. There is slight egression of the final preserved whorl.

Primary ribs strong and curved forward, especially near the umbilical seam. They extend to approximately 66% of the whorl height, terminating in large nodes which are conical and sharp on the inner whorls but become rounded on the last whorl. Secondary ribs are strong, about 4.5 to each primary, arching forward slightly on the venter.

Remarks: This phragmocone bears strong resemblance to the inner whorls on the holotype of *T. stelcki* Warren but as discussed elsewhere (p. 167) the outer preserved whorl of that specimen egresses and becomes rounded in section, losing the lateral shoulder, large nodes and gently arched venter typical of *Teloceras*. Thus it is here suggested (p. 167) that *T. stelcki* Warren is not a true *Teloceras*. The nature of the body chamber of the present specimen remains unknown, but already the whorls of the phragmocone exhibit uncoiling, suggesting doubtful affinity with *Teloceras*.

Genus *Epalxites* Mascke, 1907

Type Species: *Epalxites anceps* (Quenstedt, 1886), by original designation.

?*Epalxites* sp. indet. ♂ [microconch]

(Pl. 11, fig. 4; Text-fig. 48)

Material: GA 1035d, from the collection of Mr F. Garcia, E. N. A. P. (Inst. Geol., Univ. Nac., Santiago) from Salar de Pedernales, Atacama Province, Chile. Specimen referred to by Westermann and Riccardi (1972a, p. 20). Complete microconch with lappet, body chamber laterally crushed.

Description: The adult shell reached a diameter of approximately 62 mm

Text-fig. 48. Cross-section through phragmocone and body chamber (shaded) of ?*Epalxites* from Salar de Pedernales, Chile; GA 1035d, x 1.

at the aperture which is marked by lateral lappets. Body chamber coronate, depressed (H/W = 0.56), just over half a whorl in length, with broad and almost flat venter at adapical end, an abrupt lateral shoulder and steep flanks. Primary ribs curved forward, strong, reaching to 75% of whorl height and terminating in large, round nodes situated along the lateral shoulder; 12 on the last half-whorl. Secondary ribs finer, slightly convex forward, outnumbering primary ribs 4:1. On the phragmocone whorls the flanks are a little more inflated but the abrupt shoulder and almost flat venter are present. Primary ribs finer and sharp, 10 per half-whorl, curved forward with smaller, sharp nodes.

Remarks: Numerous species of the genus have been described by Westermann (1954) from western Europe, all from the Sauzei Zone or lowermost Humphriesianum Zone. Compared with the present specimen these all have more rounded whorls with narrower venter, stronger and straighter primary ribs and larger, spinose tubercles.

Stephanoceratidae gen. et sp. indet. A

(Pl. 8, fig. 6; Text-fig. 49b)

Material: About one quarter of a whorl, with one side corroded, from 10-15 m above the exposed base of the Yakoun Formation at MacKenzie Bay, Queen Charlotte Islands. McM J1860.

Description: This small fragment is figured because of its distinctive features. The whorl section is much wider than high, coronate, with slightly inflated flanks, abrupt lateral shoulder and broad, gently arched venter (Text-fig. 49b).

Ornamentation is very strong. Primary ribs are slightly curved forward, becoming massive on the upper flanks and terminating in large, conical tubercles situated along, but protruding above, the lateral shoulder. Secondary ribs, formed by trifurcation at each tubercle, arch forward across the venter and are of greater relief.

Stephanoceratidae gen. et sp. indet. B ?♀ [macroconch]

(Pl. 8, fig. 4)

Material: GSC 858 collected by Sutherland Brown at MacKenzie Bay, Queen Charlotte Islands. Half-whorl of phragmocone with two fragments of the succeeding body chamber whorl attached.

Remarks: In whorl dimensions and coiling this specimen is very similar

Text-fig. 49. Stephanoceratidae gen. et sp. indet. (a) cross-section through part of the phragmocone whorls of sp. C, x 1; McM J1861; (b) cross-section of part of a phragmocone whorl of sp. A, x 1; McM J1860.

to Stephanoceratidae gen. et sp. indet. C (Text-fig. 49a) from the same locality. It differs in having less sharp, rectiradiate primary ribs which, on the body chamber, become very broad on the flanks.

Stephanoceratidae gen. et sp. indet. C ?♀ [macroconch]

(Pl. 8, fig. 5; Text-fig. 49a)

Material: A single phragmocone specimen, McM J1861, 80 mm in diameter, fully septate, with only one side of the whorls preserved and much of the venter damaged. From MacKenzie Bay, Queen Charlotte Islands, 10-15 m above the exposed base of the Yakoun Formation.

Description: Outermost preserved whorl coronate with convex flanks, abrupt lateral shoulder and almost flat venter (Text-fig. 49a). Umbilical seam runs along line of tubercles on next inner whorl. No measurements of whorl dimensions possible due to fragmentary nature of specimen.

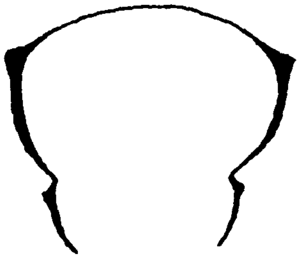
Primary ribs strong, sharp on inner whorls, strongly curved forward approaching the umbilical seam, terminating in prominent, round tubercles situated along the lateral shoulder at 75% of the whorl height. Secondary ribbing very strong, curving forward slightly from the tubercles; approximately three times as dense as the primary ribbing. Suture only partially known: large, trifid L and strongly oblique umbilical lobes.

Remarks: The outer whorl of the present specimen resembles the septate holotype of *Teloceras itinsae* McLearn, which was found as float at this same locality, but owing to uncertain generic affinity of that specimen (p. 166) no formal comparison is made.

Stephanoceratidae gen. et sp. indet. D [?*Cadomites*]

(Pl. 11, fig. 2; Text-fig. 50)

Material: McM J1779g, a quarter-whorl, probably phragmocone, silicified, with part of the next inner whorl attached. From Caracoles, Antofagasta Province, Chile.



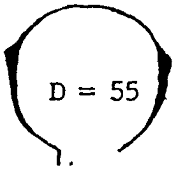
Text-fig. 50. Stephanoceratidae gen. et sp. indet. D [?*Cadomites*] McM J1779g, x 1. Cross-section through probable phragmocone whorls.

Description: Whorl section depressed (H/W = 0.70) with broad, gently arched venter, pronounced lateral shoulder and slightly inflated flanks (Text-fig. 50). Primary ribs broad and strong, curved forward on lower flanks, reaching maximum relief on mid-flanks, then decreasing in relief and becoming radial; terminate in large, round tubercles situated on the lateral shoulder at about 60% of the whorl height. Primary ribs widely spaced with about 9 per half-whorl; sharp secondary ribs outnumber primaries 4:1, arching gently forward across the venter.

Remarks: The long, curved primary ribs and densely spaced, sharp secondary ribs are similar to the style of ornamentation on *Cadomites* but the suture on the present specimen is unknown. It is much broader, has a more quadrate whorl section and longer primary ribs than described species of *Stephanoceras* and *Stemmatoceras*.

Stephanoceratidae gen. et sp. indet. E [?*Cadomites*]

(Pl. 9, fig. 2; Text-fig. 51)



Text-fig. 51. Stephanoceratidae gen. et sp. indet. E [?*Cadomites*] McM J17791, x 1. Cross-section through a whorl from the phragmocone.

Material: McM J17791, representing the last half-whorl of the phragmocone, silicified but corroded, inner whorls not preserved. From Caracoles, Antofagasta Province, Chile.

Description: The last septum is present at the end of the preserved specimen (Pl. 9, fig. 2b) and the sutures appear to be approximated and simplified, though corrosion makes this difficult to determine with certainty. Septation ceases at a diameter of 60 mm where the whorl is rounded in cross-section, being almost as high as wide (H/W = 0.88). The venter is strongly arched and curves gradually to the flanks which are slightly flattened and then curve sharply to the umbilical seam (Text-fig. 51). The umbilicus appears to have been broad and shallow, occupying about half the shell diameter.

Primary ribs are widely spaced, there being about 10 on the preserved half-whorl, strong but not sharp, terminating at about 60% of the whorl height in large, round tubercles. The finer secondary ribs outnumber the primaries 4:1 and pass straight over the venter.

Remarks: In style and density of ribbing this specimen closely resembles some of the incomplete macroconch specimens described here from the same locality (p. 154; Pl. 11, fig. 1) but has a higher and rounder whorl section. Compared with microconch North American *Stephanoceras* s. s. this specimen has denser secondary ribbing and the whorl cross-section is much more rounded and relatively narrower.

Family SPHAEROCERATIDAE Buckman, 1920

Genus *Chondroceras* Mascke, 1907

Type Species: *Chondroceras gervillii* (J. Sowerby, 1817), by original designation.

Discussion: McLearn (1927) erected two new genera for Bajocian sphaerocone ammonites from western Canada: *Defonticeras* occurring in the Queen Charlotte Islands, and *Saxitoniceras* from Alberta. He later (1949) came to regard *Defonticeras* as a subgenus of the European *Chondroceras* Mascke.

"Defonticeras" McLearn was separated from the European genus *Chondroceras* by the latter having a "3-ridged mouth, somewhat regular umbilicus, and fine ribs sloping well forward near the anterior end of the ultimate whorl" (McLearn, 1929, p. 13). Comparison of larger collections of *"Defonticeras"* from the Queen Charlotte Islands, Alberta and southern Alaska with plastotypes and figured specimens of European *Chondroceras* shows that in both groups sudden umbilical enlargement

begins about two-thirds to one-half of a whorl before the aperture, corresponding to the beginning of the body chamber. Though a three-ridged mouth border is never seen in the eastern Pacific material, it is by no means universal in European species of *Chondroceras* either (see Plates 1, 2 and 3 in Westermann, 1956a). Primary ribs on the body chamber of eastern Pacific species are coarser and more widely spaced than on European *Chondroceras* but they remain prorsiradiate, though less so than on the phragmocone whorls. On the phragmocone the primary ribs are fine, conspicuously curved and closely spaced as in European *Chondroceras*. I believe this minor variation in ornamentation of the body chamber is insufficient to warrant separation, even at the subgeneric level, and "*Defonticeras*" McLearn is here treated as synonymous with *Chondroceras* Mascke. This follows the classification adopted in the Treatise on Invertebrate Paleontology, Part L, Mollusca (Arkell, 1957, p. L292).

Two small sphaeroconic species from Alberta were distinguished by McLearn (1927, 1928) as the genus *Saxitoniceras*; they were separated from "*Defonticeras*" by having a less dissected suture line and less abrupt umbilical enlargement. Again, these minor variations are not considered sufficient for generic or subgeneric distinction. Indeed, *Chondroceras oblatum* (Whiteaves) ♀ from the Queen Charlotte Islands, tentatively placed in "*Defonticeras*" by McLearn (1929, p. 17) has a similarly simplified suture line (compare Text-figs. 57, 58) and is regarded as being conspecific with *Saxitoniceras marshalli* McLearn. "*Saxitoniceras*" McLearn is also placed in synonymy with *Chondroceras* Mascke. Umbilical enlargement in "*Saxitoniceras*" occurs suddenly over the last half- to quarter-whorl and is very similar in character to that on "*Defonticeras*".

Westermann (1956a) treated "*Defonticeras*" and "*Saxitoniceras*" as subgenera of *Chondroceras*; he later (1964a, pp. 55, 64, 65) tentatively placed "*Saxitoniceras*" in synonymy with "*Defonticeras*" as the corresponding microconch form. However, no "*Saxitoniceras*" has been found with the macroconch "*Defonticeras*" faunas on the Queen Charlotte Islands and indeed the corresponding microconchs are very much smaller than "*Saxitoniceras*" (see Pl. 12, figs. 8, 9; Pl. 13, figs. 7, 8). Both species of *Chondroceras* from the Queen Charlotte Islands are strongly dimorphic in that the macroconch is approximately three times the size of the corresponding microconchs. However, the apertural modifications in both dimorphs are similar: a constriction followed by a flared collar.

Chondroceras oblatum (Whiteaves, 1876) ♀ & ♂

(Pl. 12, figs. 1-9; Text-figs. 52-60)

Chondroceras oblatum ♀ [macroconch]

1876 *Ammonites loganianus* Form A, Whiteaves, p. 29; Pl. 4, figs. 2, 2a.

1884 *Stephanoceras oblatum* Whiteaves, p. 209.

1927 *Saxitoniceras marshalli* McLearn, p. 68.

1928 *Saxitoniceras marshalli* McLearn, p. 22; Pl. VIII, figs. 3, 4.

1929 *Defonticeras oblatum* (Whiteaves); McLearn, pp. 16, 17; Pl. XV, fig. 1.

1956a *Chondroceras (Defonticeras) oblatum* (Whiteaves); Westermann, pp. 102-4; figs. 18, 61; Pl. 11, figs. 4, 5.

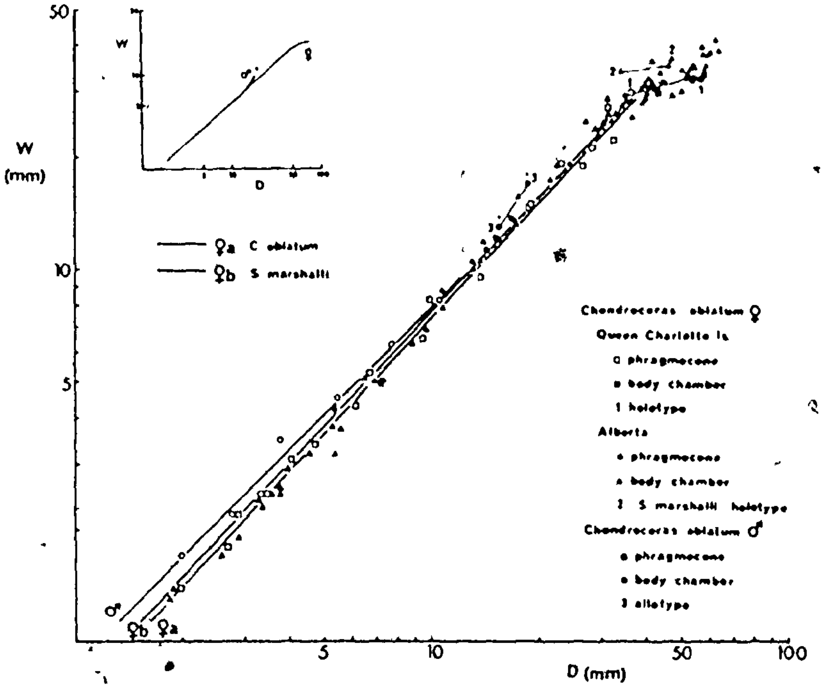
1957 *Chondroceras marshalli* McLearn var.; Frebold, p. 54; Pl. XXV, figs. 3a, b; Pl. XXVI, figs. 2a, b.

1964a *Chondroceras (Defonticeras) oblatum* (Whiteaves); Westermann, pp. 55, 64.

1964 *Chondroceras* cf. *C. marshalli* (McLearn); Imlay, p. B43; Pl. 12, figs. 1-3.

Holotype: GSC 4964, collected by J. Richardson in 1872 and labelled "Skidegate Channel". McLearn (1929, p. 17) assumed this specimen came from the lower part of the Yakoun Formation at Richardson Bay on the south shore of Maude Island. However, it does not resemble any of the specimens collected and described from that locality; it does agree closely with material from South Balch Island in Skidegate Inlet and the holotype may well have come from the lower Yakoun Formation exposed at this locality. The holotype of *"Saxitoniceras" marshalli* was originally described as coming from near the base of the Fernie Formation on the headwaters of Sheep Creek, Alberta (McLearn, 1928, p. 22).

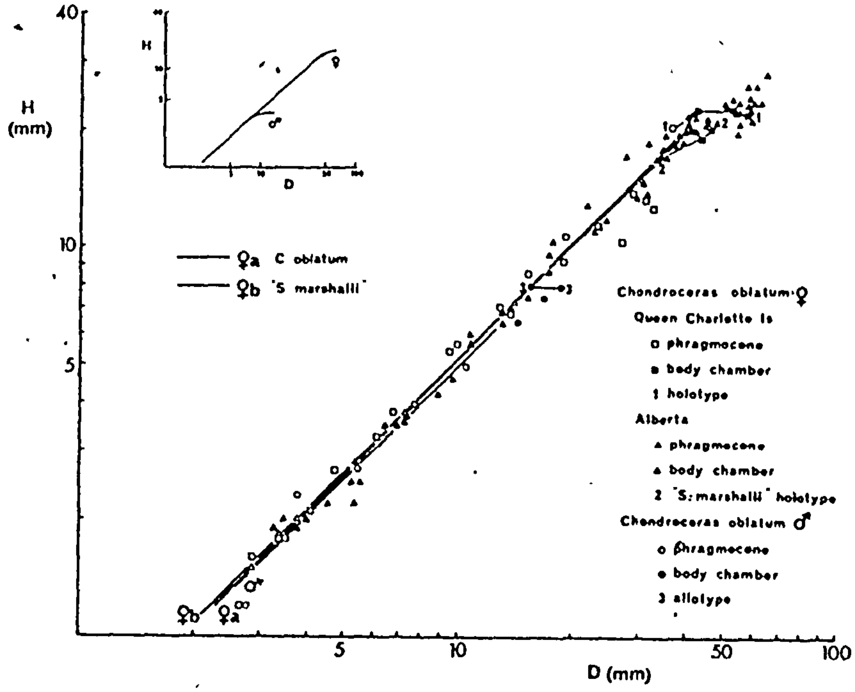
Other Material: Eleven macroconch specimens (McM J1795, 1832a-d, 1833 and 1834a, b) were obtained from several horizons in the lower Yakoun Formation on South Balch Island. Other specimens described as *"Saxitoniceras" marshalli* come from the Rock Creek Member of the Fernie Group in Ribbon Creek, southern Alberta (Frebold, 1957) and the Tuxedni



Text-fig. 52. Plot of whorl width (W) against shell diameter (D) for *Chondroceras oblatum* (Whiteaves) ♀ (5 specimens) and ♂ (3 specimens) from South Balch Island, Queen Charlotte Islands and the synonymous *"Saxitoniceras" marshalli* McLearn ♀ (17 specimens) from Ribbon Creek, southern Alberta.

Formation of southern Alaska (Imlay, 1964). Further material from the Ribbon Creek locality in southern Alberta collected by G. E. G. Westermann (McM J1837a-f) and myself (McM J1836a-f) was also studied.

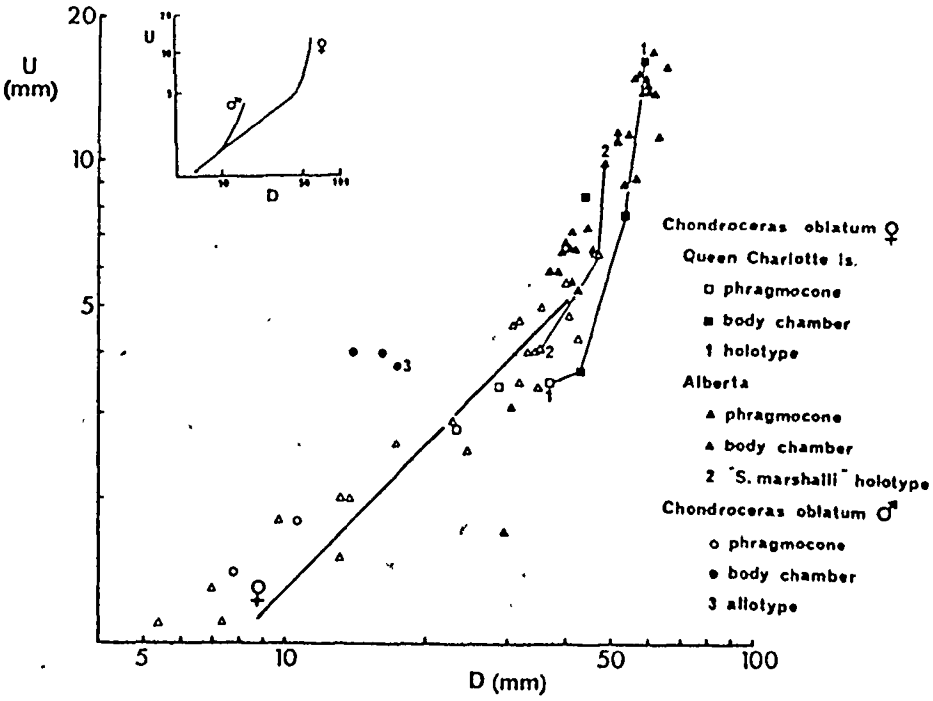
Description: The early phragmocone whorls are sphaeroconic with a rounded venter curving continuously onto the convex flanks and to the umbilical seam. The umbilicus is very narrow, usually representing less than 10% of the shell diameter. Whorls depressed, with H/W = 0.65-0.75. Prior to a diameter of 13 mm the shell is smooth. At greater diameters on the phragmocone the primary ribs are faint on the umbilical wall, somewhat stronger but never sharp on the lower flanks, almost rectiradiate,



Text-fig. 53. Plot of whorl height (H) against shell diameter (D) for *Chondroceras oblatum* (Whiteaves) ♀ (5 specimens) and ♂ (3 specimens) from South Balch Island, Queen Charlotte Islands and the synonymous *"Saxitoniceras" marshalli* McLearn ♀ (17 specimens) from Ribbon Creek, southern Alberta.

8-10 per half-whorl. There are 3.5 secondary ribs to each primary rib and they pass straight over the venter; tubercles are absent at all stages of growth.

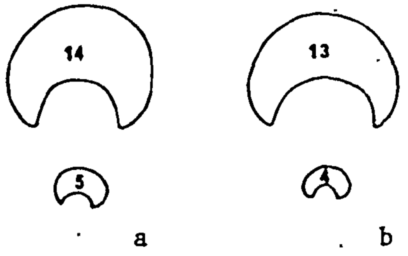
The body chamber is two-thirds of a whorl in length, egression beginning at the last septum with sudden enlargement of the umbilicus to as much as 30% of the shell diameter. Near the aperture the whorl section remains depressed with H/W ratios of 0.70-0.75; the venter remains broadly rounded but the flanks are slightly flattened. There are 8 or 9 primary ribs on the last half-whorl, slightly prorsiradiate on the flanks and giving rise to three secondary ribs per primary. Maximum diameters



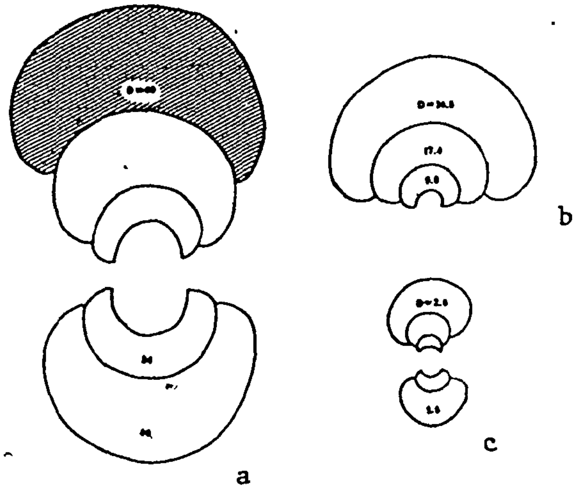
Text-fig. 54. Plot of umbilical diameter (U) against shell diameter (D) for *Chondroceras oblatum* (Whiteaves) ♀ (5 specimens) and ♂ (3 specimens) from South Balch Island, Queen Charlotte Islands and the synonymous *"Saxitoniceras" marshalli* McLearn ♀ (17 specimens) from Ribbon Creek, southern Alberta.

attained are 55-60 mm, the aperture being marked by a narrow constriction followed by a smooth lip.

Remarks: This species is clearly differentiated from *C. defontii* ♀ and *Chondroceras* n. sp. indet. ♀ by ribbing density and sutural complexity. *C. defontii* ♀ is characterised by complex sutures which are deeply incised whereas the suture of *C. oblatum* ♀ has broader saddles with small incisions. While also having a simple suture, *Chondroceras* n. sp. indet. ♀ has much denser and finer ribbing (12-14 primaries per half-whorl) and a broader whorl section than *C. oblatum* ♀ (H/W = 0.47-0.55 vs. 0.65-0.75 at similar diameters.

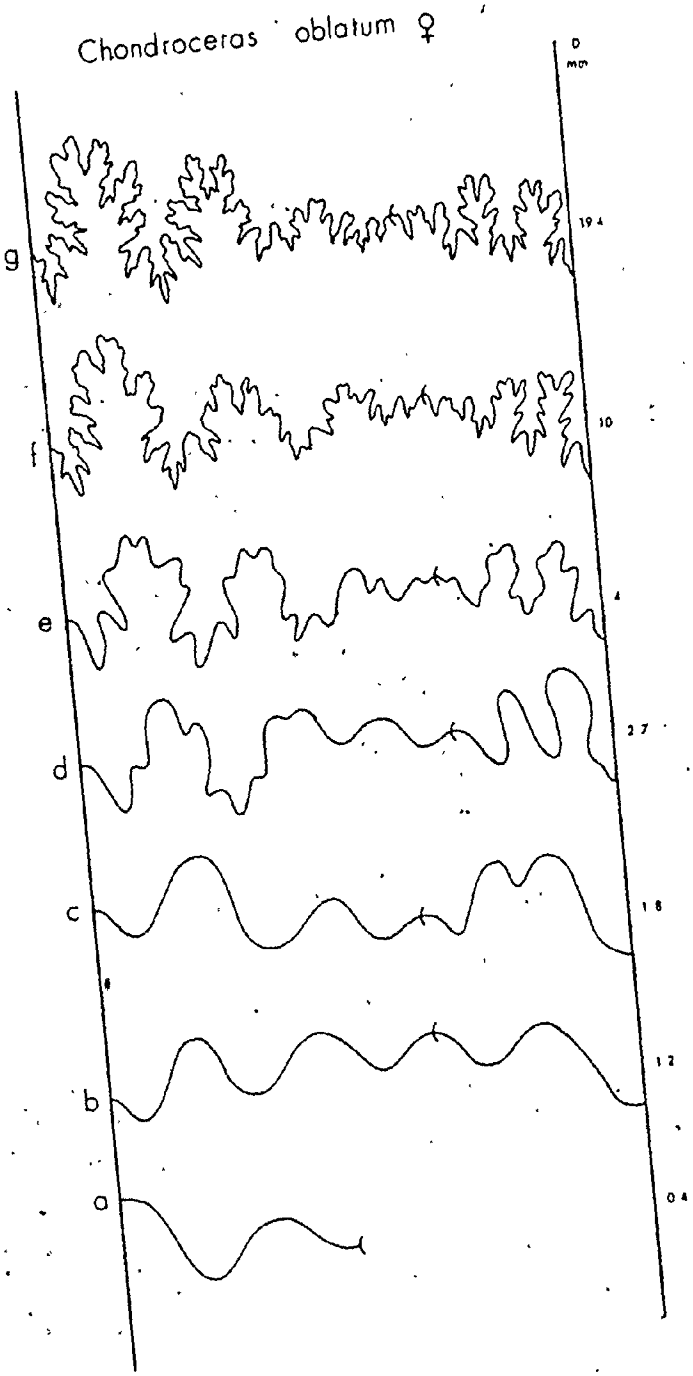


Text-fig. 55. Cross-sections of phragmocone whorls of *Chondroceras oblatum* (Whiteaves) ♀. (a) McM J1795b, x 7; (b) McM J1795a, x 7. Both from South Balch Island, Queen Charlotte Islands.



Text-fig. 56. Cross-sections of phragmocone and body chamber (shaded) of *"Saxitoniceras" marshalli* McLearn ♀ from Ribbon Creek, southern Alberta. (a) McM J1836e, x 1; (b) McM J1837g, x 1; (c) McM J1836f, x 8.

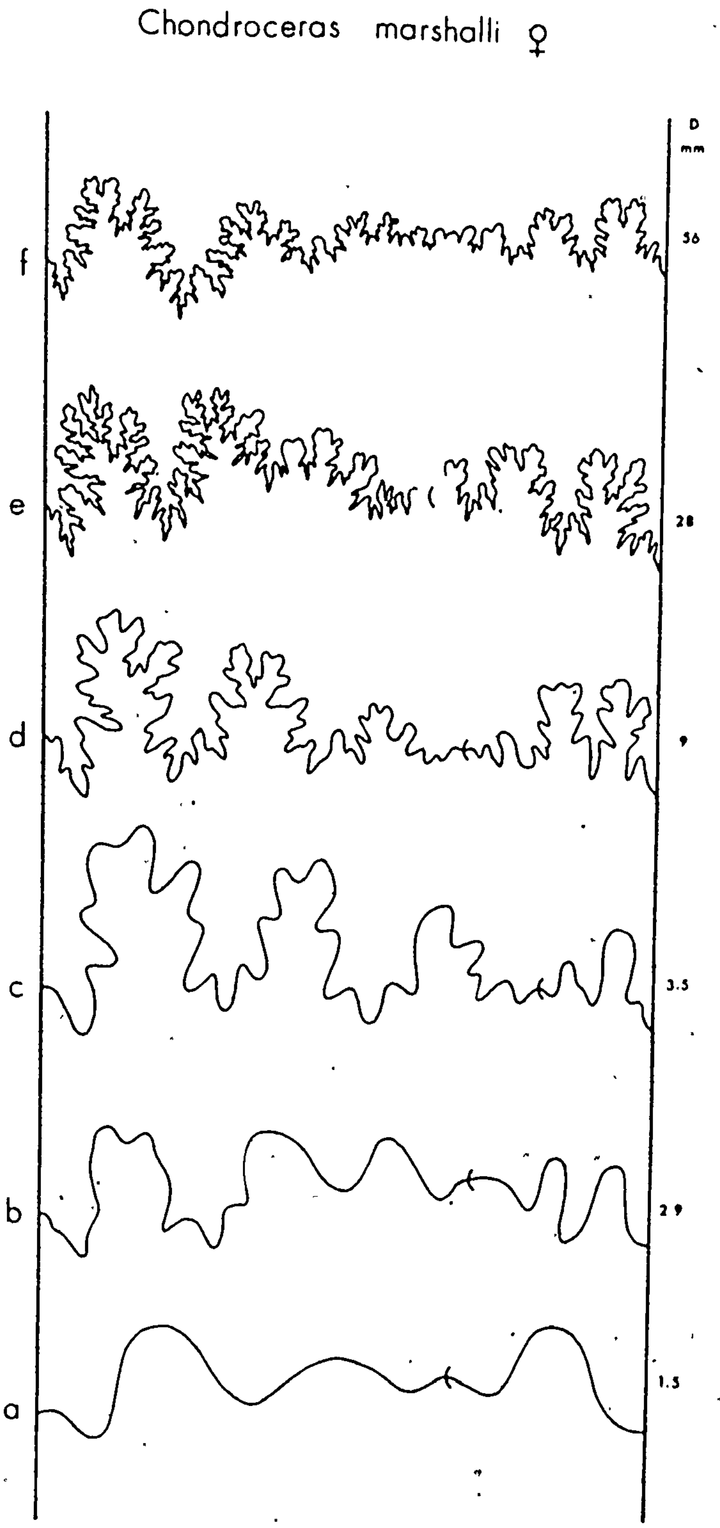
Comparison of the whorl dimensions of *"S." marshalli* ♀ with *C. oblatum* ♀ shows that the two forms are closely similar (Text-figs. 52-54). Both attain similar maximum diameters (58.7 mm for the holotype of *C. oblatum* ♀ and 51-66 mm for *"S." marshalli* ♀), have simplified sutures (Text-figs. 58, 59), depressed whorl sections with H/W = 0.60-



Text-fig. 57.

Sutural ontogeny for *Chondroceras oblatum* (Whiteaves) ♀ from South Balch Island.

a-g: McM J1795a

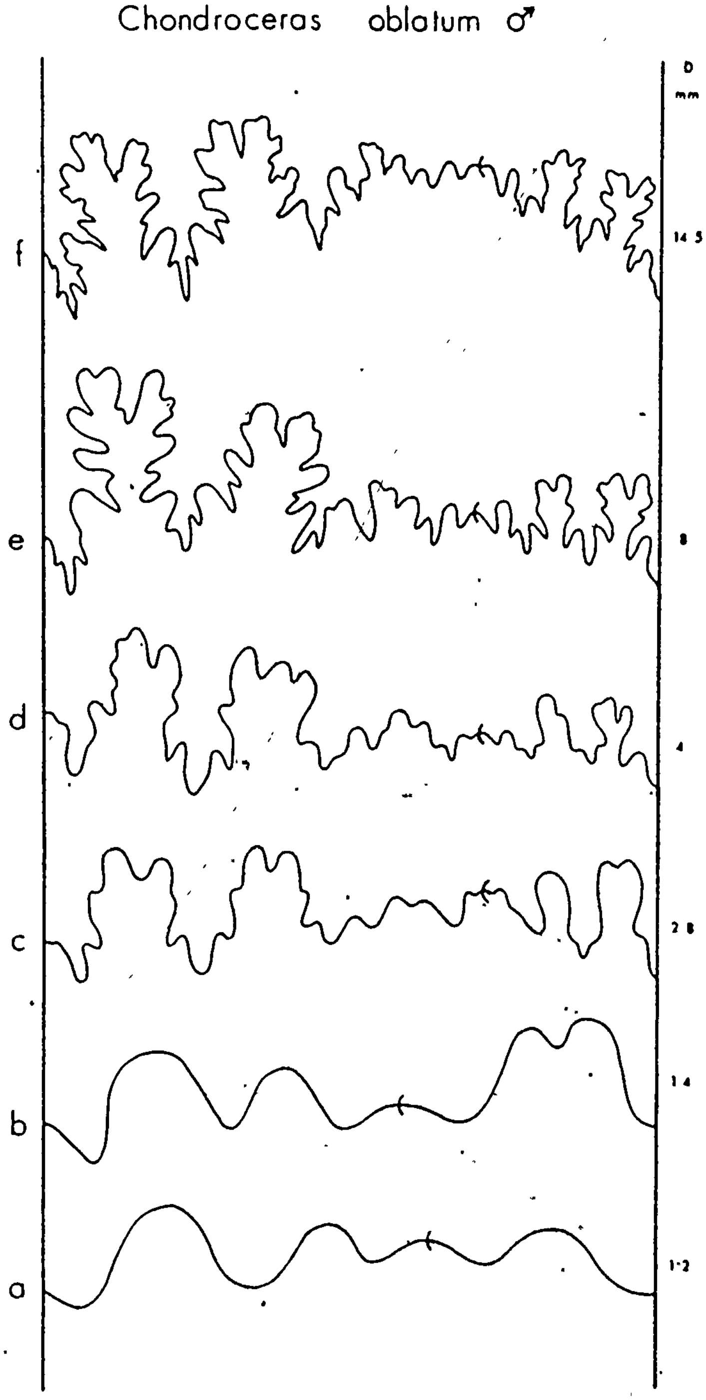


Text-fig. 58.

Sutural ontogeny for *Chondroceras "marshalli"* ♀ [= *Saxitoniceras marshalli* McLearn ♀] from Ribbon Creek.

a-e: McM J1837h

f: McM J1836d



Text-fig. 59.

Sutural ontogeny for *Chondroceras oblatum* (Whiteaves) ♂ from South Balch Island.

a-f: McM J1794b.

0.80 and 7-10 primary ribs on the last half-whorl of the body chamber with three secondaries to each primary. Thus *C. oblatum* (Whiteaves) and "*S.*" *marshalli* McLearn are placed in synonymy, the former name taking precedence.

Chondroceras oblatum ♂ [microconch]

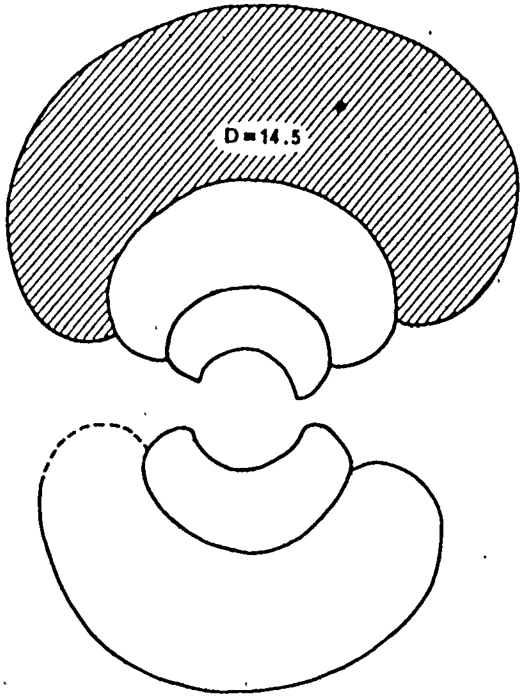
This dimorph has not been previously described.

Allotype: McM J1794a, from the lower part of the Yakoun Formation, eastern shore of South Balch Island, Queen Charlotte Islands.

Other Material: One other complete specimen, McM J1835, from 44 m above the base of the exposed Yakoun Formation on South Balch Island.

Description: Microconchs are characterised by egression of the last quarter-whorl which terminates with a narrow constriction followed by a smooth lip. Microconchs reach a maximum size of 19 mm, only one-third the size of the adult macroconchs. The shell is oblate with a broadly rounded venter, narrow umbilicus and convex flanks. Primary ribs are slightly prorsiradiate with 7 on the last half-whorl; there are three secondaries to each primary rib at this stage. Dimensions and suture are similar to those of the macroconch (Text-figs. 52-54, 60).

Dimorphism: Text-figs. 52-54 show that the whorl dimensions of the few known microconchs are very close to those of the macroconchs. Ribbing style and density on the body chambers of the two dimorphs are very similar, while the apertural modifications are identical: a narrow



Text-fig. 60. Cross-section of phragmocone and body chamber (shaded) of *Chondroceras oblatum* (Whiteaves) ♂; McM J1794b, x 6 (approx.).

constriction followed by a broad, smooth collar. The macroconch is approximately three times the size of the microconch. No microconch specimens are known from the Ribbon Creek locality of southern Alberta.

Westermann (1964a, p. 65) considered that "*Saxitoniceras*" *allani* was a possible microconch equivalent of "*Defonticeras*" *oblatum* However, the microconchs here described and figured from the macroconch type locality on South Balch Island are very much smaller than either the macroconch *C. oblatum* or "*S.*" *allani*; no specimens similar to "*S.*" *allani* have been found on the Queen Charlotte Islands.

Chondroceras defontii (McLearn, 1927) ♀ & ♂

(Pl. 13, figs. 1-8; Text-figs. 61-65)

Chondroceras defontii ♀ [macroconch]

1927 *Defonticeras defontii* McLearn, p. 72; Pl. 1, fig. 3.

1929 *Defonticeras defontii*; McLearn, pp. 13, 14; Pl. XII, figs. 1-3.

1929 *Defonticeras colnetti* McLearn, pp. 15, 16; Pl. XIII, figs. 4, 5.

1929 *Defonticeras ellsi* McLearn, p. 16; Pl. XIII, figs. 2, 3; Pl. XIV, fig. 1.

1929 *Defonticeras marchandi* McLearn, pp. 14, 15; Pl. XII, figs. 4, 5.

1949 *Chondroceras (Defonticeras) defontii* (McLearn); McLearn, pp. 10, 16.

1956a *Chondroceras (Defonticeras) defontii* (McLearn); Westermann, pp. 100-102; Pl. 11, fig. 3; Figs. 57, 59.

1964 *Chondroceras defontii* (McLearn); Imlay, p. B42; Pl. 12, figs. 8, 11-14.

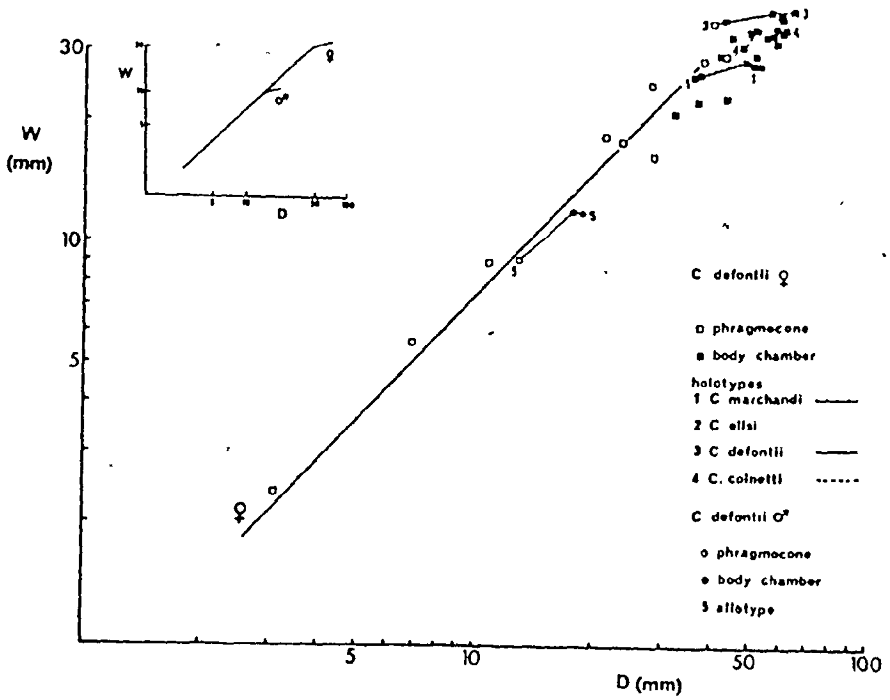
Holotype: GSC 9009, from talus on the ledges of the lower Yakoun Formation at Richardson Bay on the south shore of Maude Island, Queen Charlotte Islands.

Other Material: Seven complete, though sometimes crushed, macroconchs (McM J1792a-f, J1829) and a number of body chamber fragments complete with aperture from the type locality.

Description: Phragmocone whorls globose with broadly rounded venter, inflated flanks and short, steep umbilical wall. Umbilicus very narrow, usually less than 10% of the shell diameter, and deep. Cross-section depressed with H/W ratios of 0.60-0.75. Primary ribs are fairly strong, rectiradiate on the steep umbilical wall, then strongly curved forward on the lower flanks; 11 to 15 per half-whorl. Secondary ribs fine and closely spaced, up to 3.5 per primary, curved forward from the point of furcation and then crossing straight over the venter. Nodes not developed.

Egression of the body chamber is abrupt, beginning close to the last septum, with a sudden increase in umbilical diameter from less than 10% to 20-25% of the shell diameter. The body chamber occupies one-half to two-thirds of a whorl and terminates with a strong constriction and a broad, smooth lip. There is a decrease in relative whorl width and height (Text-figs. 61, 62) near the aperture but the whorl remains broadly rounded with H/W ratios of 0.65-0.75; the flanks become slightly flattened with loss of the steep umbilical wall seen on earlier whorls. Maximum diameters are between 51 and 65 mm. Ornamentation on the body chamber remains strong right to the aperture. Primary ribs are straight and more widely spaced but directed forward on the flanks with 10-13 on the last half-whorl. The density of secondary ribs is reduced to 2.5 to each primary and they are noticeably coarser than those on the phragmocone.

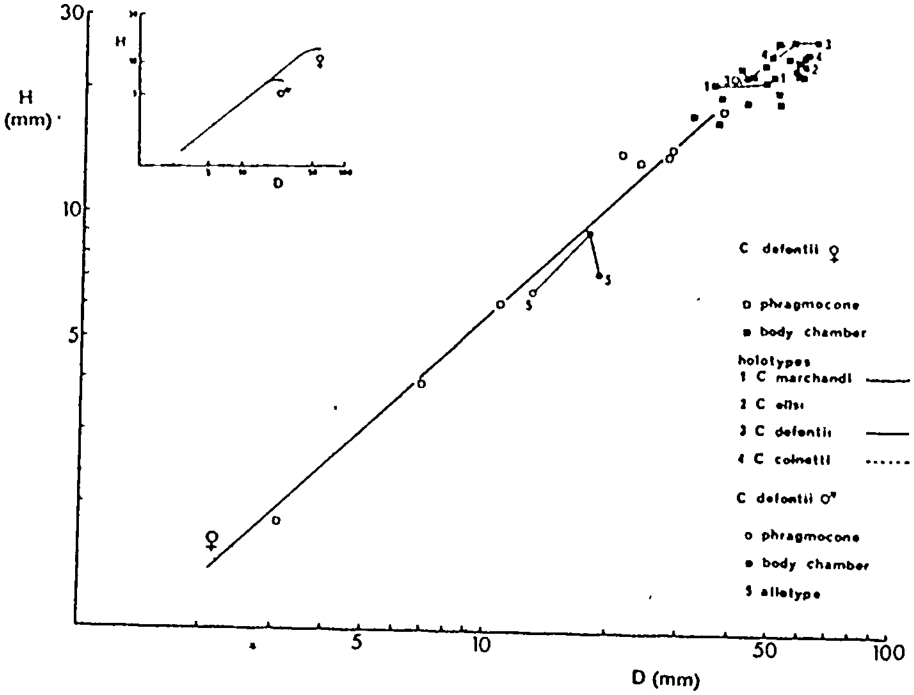
The mature suture (Text-fig. 65) is complex with deeply incised



Text-fig. 61. Plot of whorl width (W) against shell diameter (D) for *Chondroceras defontii* (McLearn) ♀ & ♂ and synonymous "species" from Richardson Bay, Queen Charlotte Islands. Measurements from 13 macroconch and 1 microconch specimen.

saddles. E/L is only a little higher than L/U_2 but U_2/U_3 is very short and broad. L is about as deep as E and trifid, while U_2 is broader and trifid. The umbilical lobes are short and not retracted.

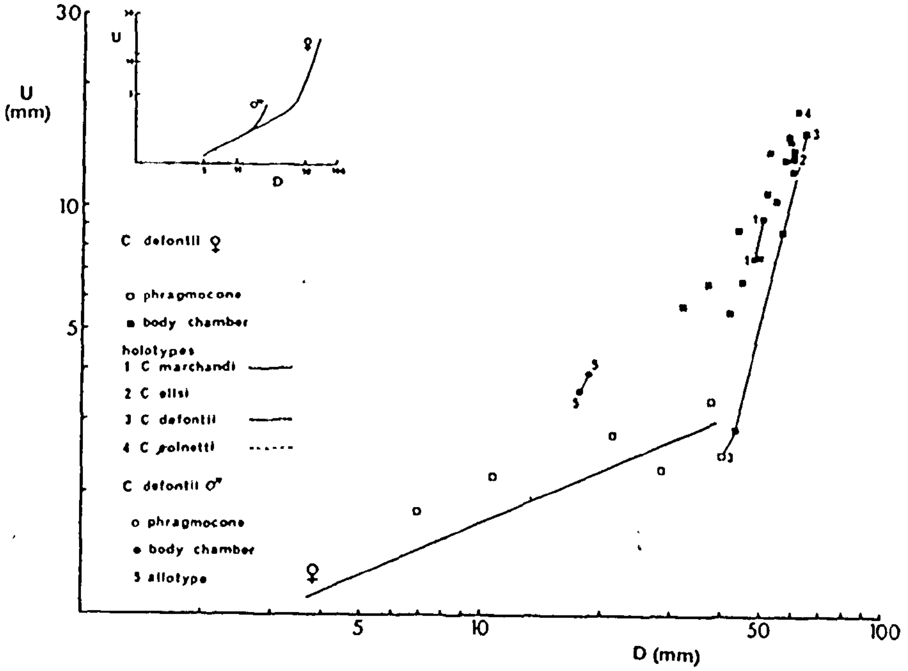
Remarks: *Chondroceras defontii* ♀ usually has 10-13 primary ribs per half-whorl on the body chamber and last parts of the phragmocone and up to 15 per half-whorl on earlier whorls. This density is similar to that seen on *Chondroceras* sp. from MacKenzie Bay (p. 205), but *C. defontii* ♀ has a more complex suture with longer and narrower lobes and much more deeply incised saddles (compare Text-figs. 65, 72); its whorl section is also narrower and higher.



Text-fig. 62. Plot of whorl height (H) against shell diameter (D) for *Chondroceras defontii* (McLearn) ♀ & ♂ and synonymous "species" from Richardson Bay, Queen Charlotte Islands. Measurements from 13 macroconch and 1 microconch specimen.

C. oblatum (Whiteaves) ♀ is separated by having a simpler suture line with broader and less deeply incised saddles (compare Text-figs. 57, 65), fewer primary ribs on the body chamber whorl and coarser secondary ribbing on the phragmocone. *C. oblatum* ♀ also has a broader cross-section with H/W ratios of 0.60-0.65 compared with 0.65-0.75 on *C. defontii* ♀.

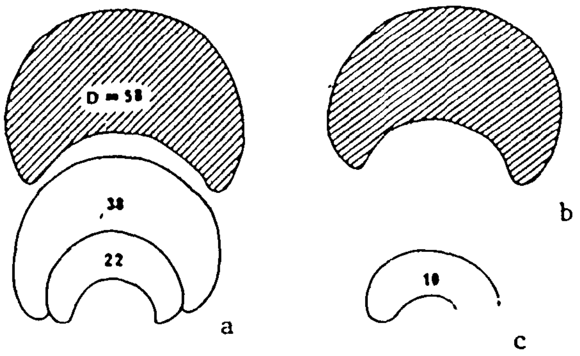
No specimens intermediate in size between the holotypes of *C. defontii* ♀ and the larger *C. maudense* (McLearn) from the same locality have been found and so the latter is retained as a separate, though poorly defined, species. A specimen described as *C. defontii* by Imlay (1964; Pl. 12, fig. 8) has a diameter close to that of the holotype of



Text-fig. 63. Plot of umbilical diameter (U) against shell diameter (D) for *Chondroceras defontii* (McLearn) ♀ & ♂ and synonymous "species" from Richardson Bay, Queen Charlotte Islands. Measurements from 13 macroconch and 1 microconch specimen.

C. maudense (75 mm just behind the aperture) but has much finer, denser ribbing with 18 primary ribs on the last half-whorl.

The four species of *"Defonticeras"* erected by McLearn (1929) from Richardson Bay were each based on a single specimen. *C. colnetti* was distinguished from *C. defontii* as being smaller with narrower whorls and a more strongly contracted body chamber. Table 9 shows that *C. defontii*, with a maximum shell diameter of 66 mm, is at the upper extreme of a range in shell sizes that includes *C. colnetti*, *C. ellsi* and *C. marchandi* and a number of other specimens of intermediate sizes. No whorl measurements from the phragmocone of *C. colnetti* are available due to poor preservation so that relative contraction of the body chamber

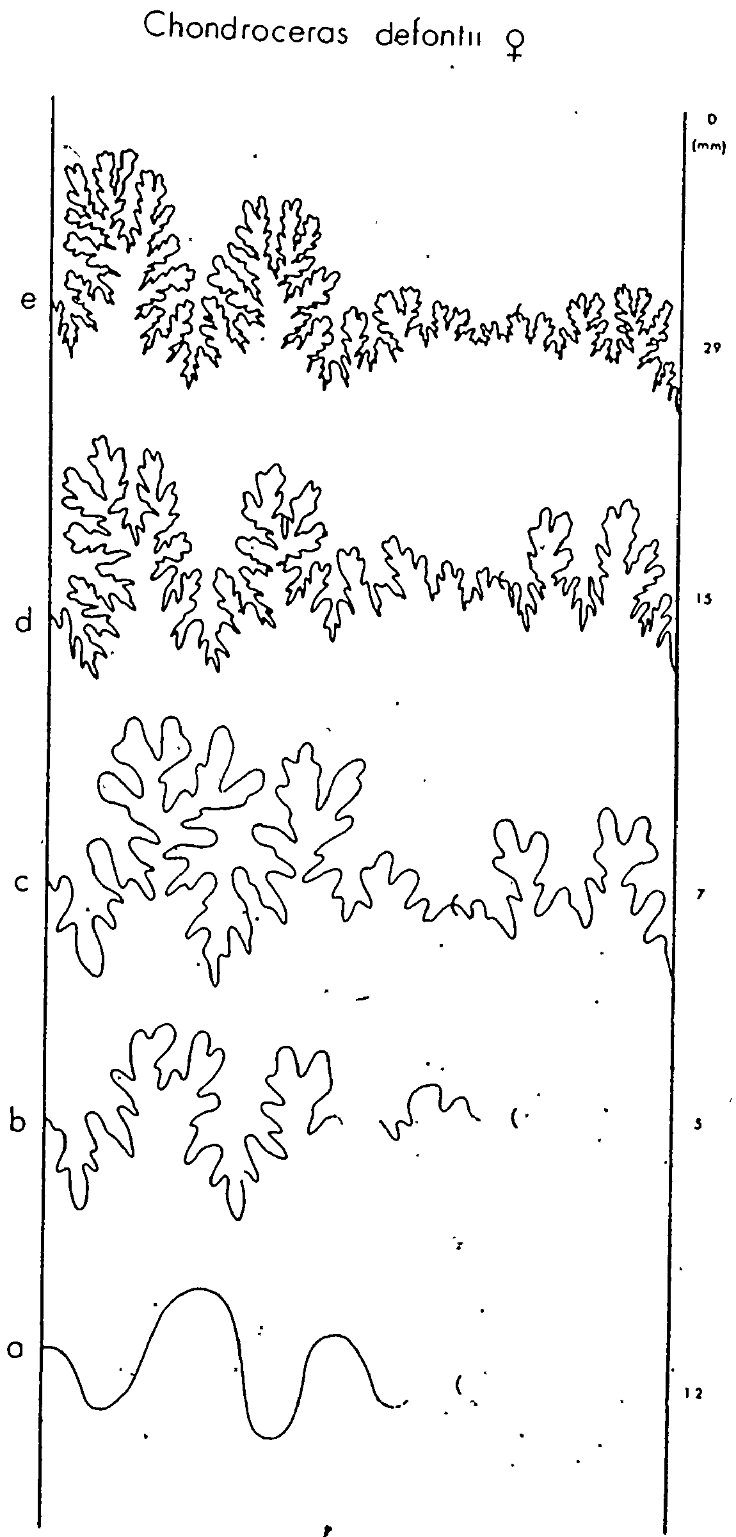


Text-fig. 64. Cross-sections of the phragmocone and body chamber (shaded) of *Chondroceras defontii* (McLearn) ♀. (a) McM J1792c, x 1; (b) McM J1792b, x 1; (c) McM J1792c, x 2.

cannot be estimated; the body chamber is only slightly narrower than that on the holotype of *C. defontii*.

C. ellsi was characterised by having narrower and lower whorls, more rounded flanks, less arched venter and deeper saddles than the holotype of *C. defontii*. A slight difference in rounding of the venter and flanks is too subjective a basis for distinction. The published figures (McLearn, 1929; compare Pl. XII, fig. 1 and Pl. XIII, figs. 2, 3) show little difference in the suture; in addition, the suture illustrated for *C. ellsi* is probably almost a half-whorl before the last septum while that for *C. defontii* appears to be the last septum.

C. marchandi is at the lower extreme of the range for maximum shell diameters in this group and the relative width and height of the body chamber (phragmocone not preserved on the holotype) are closely similar to those of the other specimens from this locality (Table 9). Secondary ribs on the last half-whorl of the body chamber are not more



Text-fig. 65.

Sutural ontogeny for *Chondroceras defontii* (McLearn) ♀.

a–e: McM J1792c.

numerous than on other specimens of *C. defontii*, as stated by McLearn (1929, p. 15).

Specimen	Maximum Diameter (mm)	U%	W%	H%	H/W	Primary Ribs *	Secondary Ribs *
C. defontii (holotype)	66	24	58	41	0.70	12	30
C. colnetti (holotype)	63	28	55	40	0.73	10	27
C. ellsi (holotype)	62	22	55	38	0.68	11	28
McM J1792a	61.5	23	59	40	0.68	13	31
McM J1792f	61	21	61	36	0.59	11	27
GSC48594	60	25	58	40	0.70	11	30
McM J1792c	59.5	15	53	37	0.70	12	29
McM J1792b	59	23	57	39	0.68	11	32
GSC48594	54	14	52	34	0.64	13	37
McM J1792e	51	21	57	38	0.67	12	30
C. marchandi (holotype)	51	19	55	43	0.78	10	27

Table 9. Comparative measurements for *Chondroceras defontii* (McLearn) ♀, with synonyms, from Richardson Bay, Queen Charlotte Islands. * number of ribs per half-whorl.

Chondroceras defontii (McLearn) ♂ [microconch]

This dimorph has not been previously described.

Allotype: McM J1793a, from Richardson Bay, Queen Charlotte Islands, 18–21 m above the exposed base of the Yakoun Formation.

Other Material: McM J1792g and GSC 48594, both from Richardson Bay, Queen Charlotte Islands.

Description: Maximum diameter attained is 19 mm, about one-third the size of the corresponding macroconchs. The aperture is marked by a prominent, narrow constriction followed by a narrow, smooth lip; the body chamber occupies three-quarters of a whorl. The whorl section is slightly depressed with H/W = 0.60–0.75; the venter is broad and rounded, the flanks slightly flattened. Primary ribs are strong and curved forward; there are nine on the last half-whorl with about three secondaries to each primary. Phragmocone whorls have not been preserved.

Dimorphism: The few measurements available from microconch specimens indicate that they are similar to the macroconch in whorl dimensions (Text-figs. 61–63). Microconchs reach about one-third the size of corresponding macroconchs. Style and density of ribbing on the body chamber are similar in both dimorphs; apertural modifications are also similar, consisting of a constriction followed by a smooth lip.

Chondroceras allani (McLearn, 1927) ♀ [macroconch]

(Pl. 14, figs. 1, 2; Text-figs. 66–71)

1927 *Saxitoniceras allani* McLearn, p. 72; Pl. 1, fig. 4.

1928 *Saxitoniceras allani*; McLearn, pp. 21, 22; Pl. VIII, figs. 1, 2.

1956 *Chondroceras (Saxitoniceras) allani* (McLearn); Westermann, pp. 107, 108; Pl. 12, fig. 3 (holotype re-figured).

1957 *Chondroceras allani* (McLearn); Frebold, p. 53; Pl. XXVII, figs. 2a, b.

1964 *Chondroceras allani* (McLearn); Imlay, pp. B42, 43; Pl. 12, figs. 4-7, 9, 10.

1964 *Chondroceras allani* (McLearn); Frebold, pp. 20, 21; Pl. VIII, figs. 1-5.

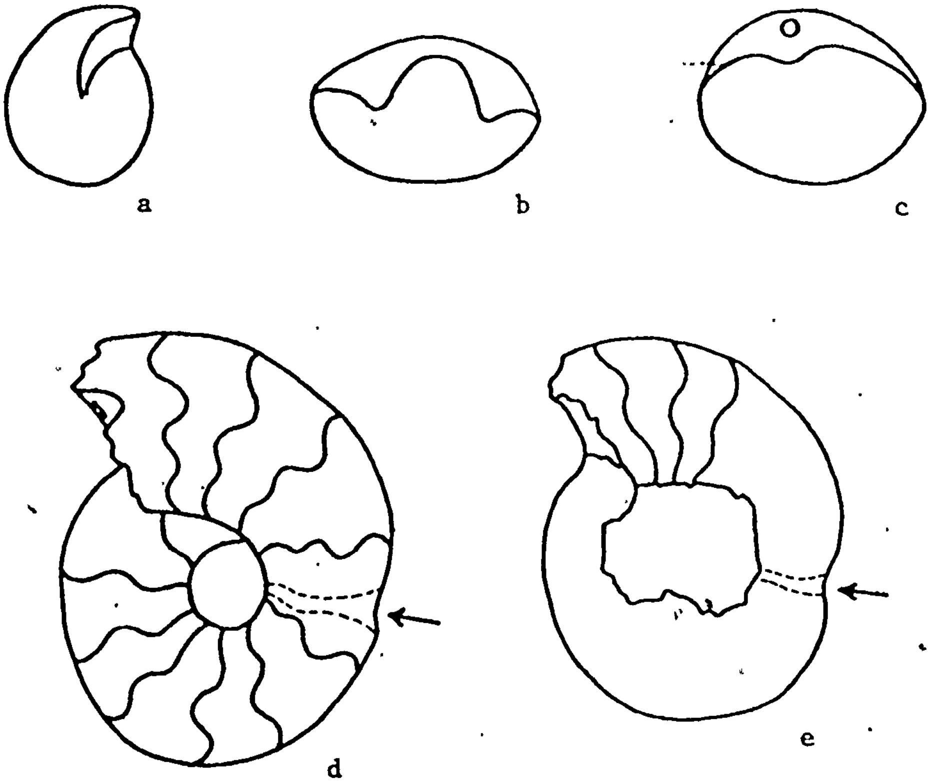
1964a *Chondroceras (Defonticeras) allani* (McLearn); Westermann, p. 55, (?microconch ♂).

1973 *Chondroceras allani* (McLearn); Imlay, p. 81; Pl. 40, figs. 11, 12.

Holotype: GSC 9021. According to the collector (quoted in McLearn, 1928, p. 22) the holotype came from the base of the Fernie Group on the headwaters of Sheep Creek, Alberta. Frebold (1957, p. 53) considers this stratigraphic position unlikely since the species is an index fossil in the Middle [= Lower, here] Bajocian Rock Creek Member which never forms the base of the Fernie.

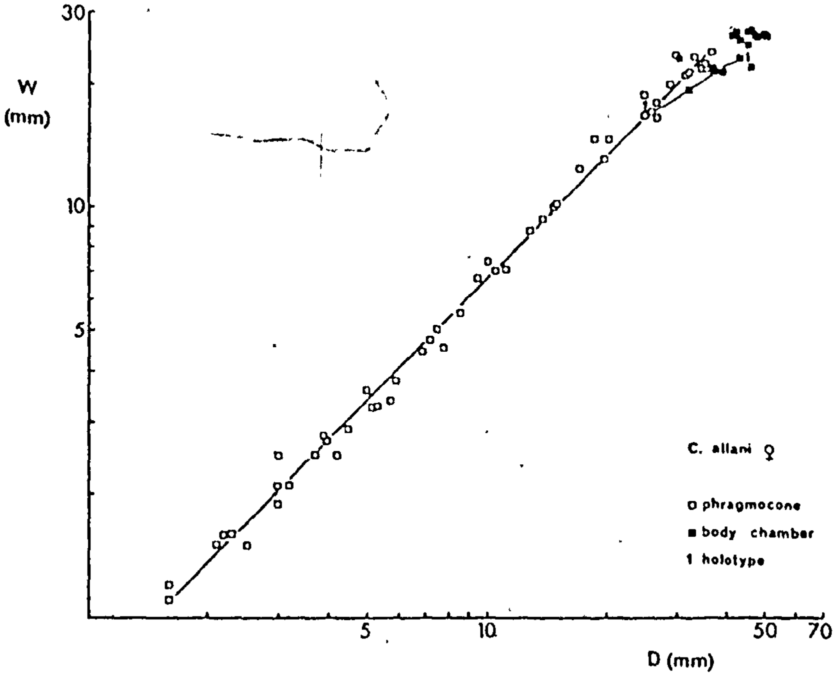
Other Material: Thirteen fairly complete specimens (McM J1830a-i, 1831a-e) collected by G. E. G. Westermann and myself from the Rock Creek Member at Ribbon Creek, southern Alberta are now available for quantitative study of the species.

Description: The protoconch is elongated transverse to the direction of coiling, having a width of 0.60 mm and a diameter of 0.50 mm at the



Text-fig. 66. Protoconch and nepionic whorl of *Chondroceras allani* (McLearn) ♀. (a), (b) and (c) three views of protoconch, McM J1830f, all x 45; (d) first whorl showing nepionic constriction in shell (arrow) and change in coiling; McM J1830f, x 45; (e) first whorl showing nepionic constriction (arrow); McM J1830c, x 45. All from Ribbon Creek, southern Alberta.

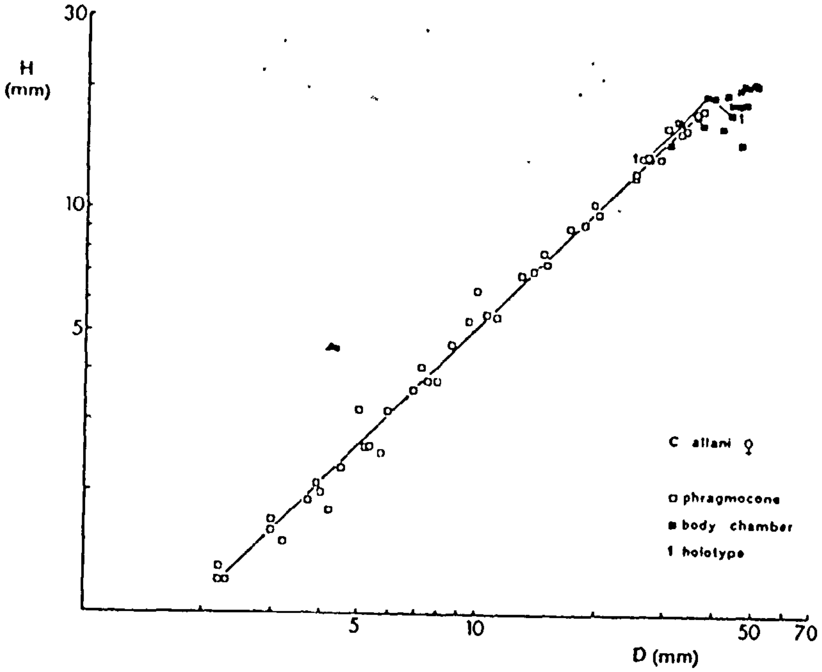
position of the proseptum. The nepionic constriction occurs at a diameter of 0.80 mm which is the end of the first whorl. Ornamentation of the shell first appears at D = 5 mm in the form of broad ribbing on the ventral region only. Faint primary ribs do not appear on the flanks until a diameter of about 12 mm is reached. Shell sphaeroconic, the phragmocone whorls moderately depressed (H/W = 0.68-0.85, mostly 0.75-0.80), with flattened flanks and a strongly arched venter. The umbilicus is deep and narrow, usually less than 5% of the shell diameter with almost vertical walls rounding smoothly onto the flanks. Ornamentation



Text-fig. 67. Plot of whorl width (W) against shell diameter (D) for *Chondroceras allani* (McLearn) ♀. Measurements from 15 specimens from Ribbon Creek, southern Alberta.

is not strong. There are 7-9 primary ribs per half-whorl, strongly curved forward on the flanks with 3-4 secondary ribs to each primary. Secondary ribs arise by bifurcation and intercalation at 50% of the whorl height, curving forward on the upper flanks then crossing straight over the venter. Nodes are absent.

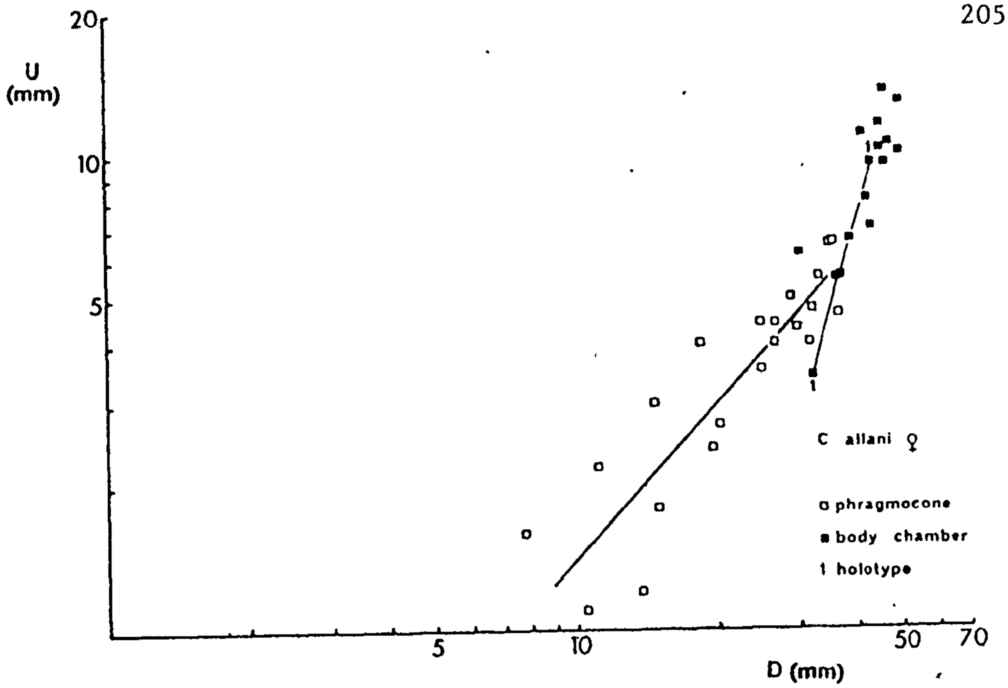
Strength and density of the ribbing remain unchanged on the body chamber except that the number of secondary ribs decreases to 2.0-2.5 per primary. The last half-whorl before the aperture bears 7-9 primary ribs curving forward on the flanks but not extending onto the umbilical wall which is smooth. Sudden umbilical enlargement, beginning about half a whorl before the aperture and corresponding approximately with the



Text-fig. 68. Plot of whorl height (H) against shell diameter (D) for *Chondroceras allani* (McLearn) ♀. Measurements from 15 specimens from Ribbon Creek, southern Alberta.

position of the last septum, is accompanied by a decrease in both the relative whorl width and height. The whorl section remains similar (H/W = 0.75-0.80). The aperture is marked by a broad and shallow constriction, and a smooth lip.

Remarks: *Chondroceras allani* ♀ and *C. oblatum* ♀ occur together in abundance in the Rock Creek Member of the Fernie Group at Ribbon Creek, southern Alberta. Comparison of six complete specimens of *C. allani* with fourteen complete specimens of *C. oblatum* shows that the former species has a consistently smaller adult diameter (41.5-50.0 mm vs. 51.2-65.7 mm). Phragmocone whorls of *C. allani* are relatively narrower than those of *C. oblatum* from the Ribbon Creek locality (H/W = 0.75 vs. 0.68; W/D = 0.68 vs. 0.74 respectively).



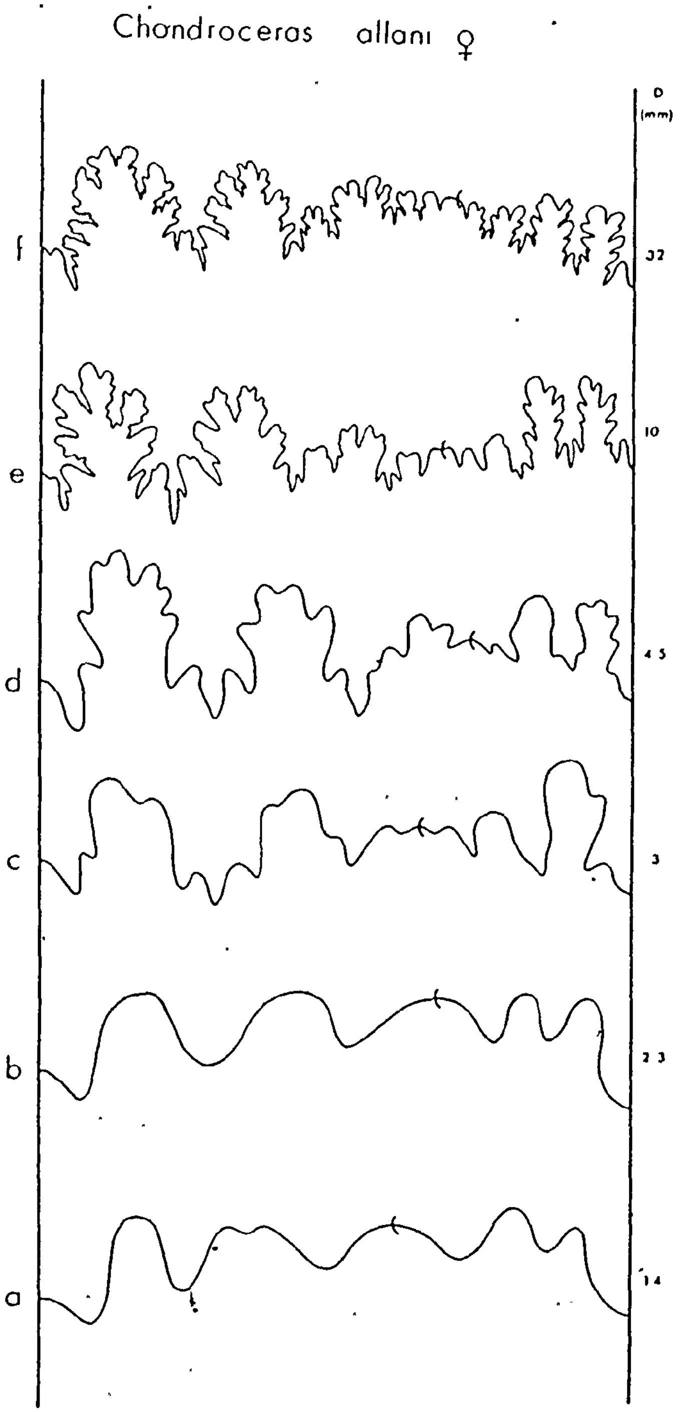
Text-fig. 69. Plot of umbilical diameter (U) against shell diameter (D) for *Chondroceras allani* (McLearn) ♀. Measurements from 15 specimens from Ribbon Creek, southern Alberta.

Chondroceras n. sp. indet. ♀ [macroconch]

(Pl. 14, fig. 3; Text-figs. 72, 73)

Material: Two incomplete phragmocones (McM J1857a, b) from the lowest exposed bed of the Yakoun Formation at MacKenzie Bay; they are the first *Chondroceras* recorded at this locality.

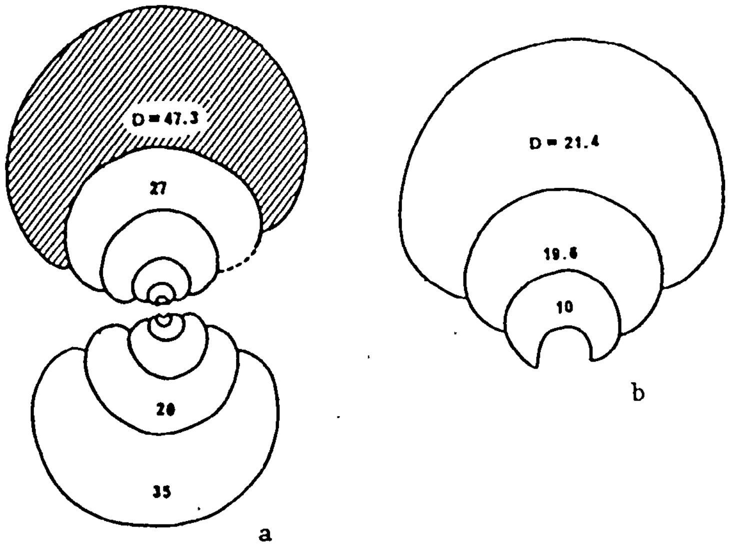
Description: Shell globose with broad and gently arched venter and a very deep, narrow umbilicus. Whorl section strongly depressed with H/W ratios of 0.50-0.65. Umbilical wall short, almost vertical, rounding strongly and rather abruptly onto the inflated flanks to produce an umbilical shoulder. Table 10 gives whorl measurements and rib counts for these two specimens.



Text-fig. 70.

Sutural ontogeny for *Chondroceras allani* (McLearn) ♀.

a–c, e–f: McM J1830h
d: McM J1830c

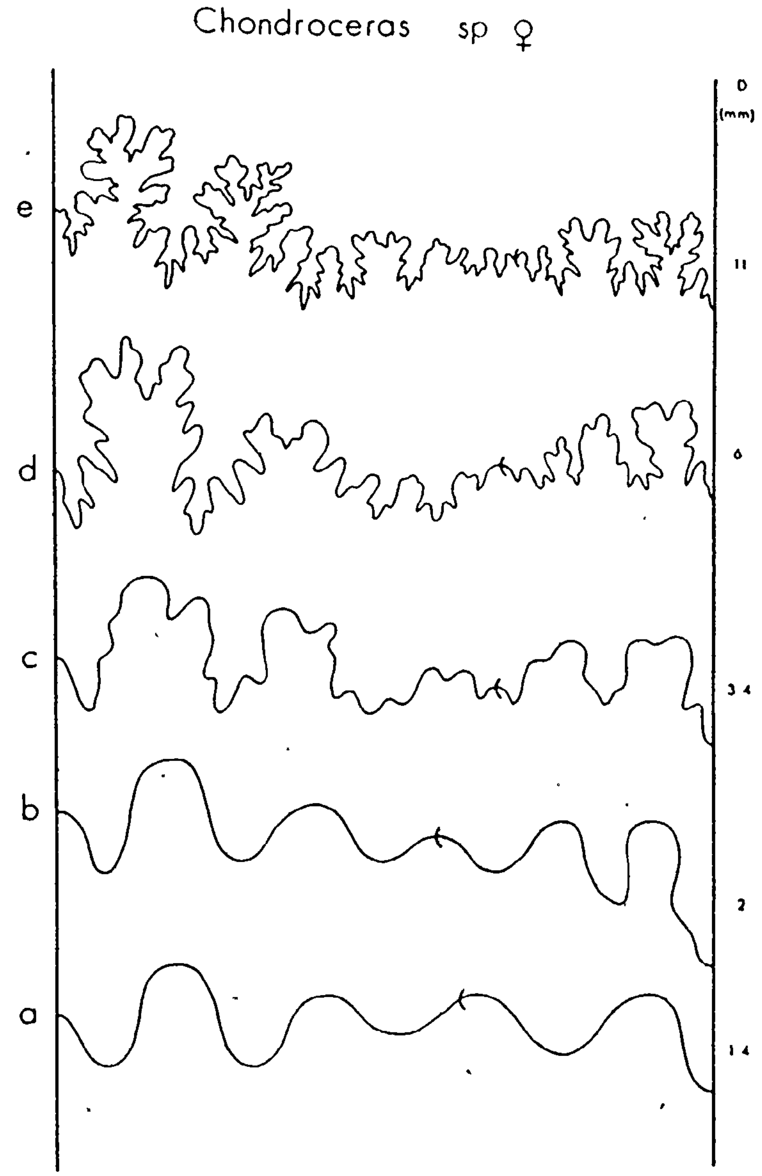


Text-fig. 71. Cross-sections of phragmocone and body chamber (shaded) of *Chondroceras allani* (McLearn) ♀ from Ribbon Creek, southern Alberta. (a) McM J1830g, x 1.5; (b) McM J1830h, x 3.

Primary ribs long and fine, beginning at the umbilical seam and extending beyond the umbilical shoulder; they are closely spaced with 12-14 per half-whorl at diameters between 13 and 33 mm. There are usually three secondary ribs to each primary. On the umbilical wall the primary ribs are straight but crossing onto the flanks become prorsiradiate; the fine secondary ribs cross straight over the venter. Nodes are not developed.

The suture is only moderately complex at a diameter of 11 mm, lacking any deep incisions of the saddles (Text-fig. 72). E is shallow and broad, L slightly deeper, broad and trifid. U_2 is very broad, shallow and trifid. I and U_n are of the same length and narrow.

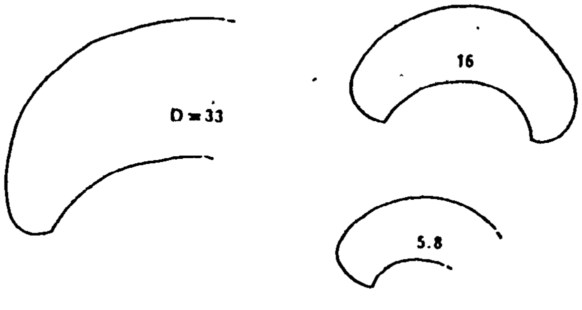
Remarks: These two phragmocones differ from *C. defontii* ♀ and



Text-fig. 72.

Sutural ontogeny for *Chondroceras* n. sp. indet. ♀ from MacKenzie Bay.

a-e: McM J1857b



Text-fig. 73.

Cross-sections of phragmocone whorls of *Chondroceras* n. sp. indet. ♀ from MacKenzie Bay. (a) McM J1857b, x 2; (b) McM J1857a, x 2; (c) McM J1857a, x 5.

C. oblatum ♀ in details of the septal suture, ribbing density and whorl shape. *C. defontii* ♀ has much more complex sutures with deeply incised saddles and narrow lobes. *C. oblatum* ♀ has fewer primary ribs per half-whorl (7-10 vs. 12-14 at D = 15-30 mm) and a higher whorl section with a narrower venter. *C. allani* ♀ has fewer primary ribs per half-whorl (8-10 vs. 12-14) and a more compressed whorl section with H/W = 0.68-0.85 on the phragmocone whorls.

Specimen number	D	U	W	H	Primary ribs *	Secondary ribs *
McM J1857a	16.0	-	14.0	7.6	14	42
	11.3	2.1	10.0	6.7	11	32
	7.8	1.5	6.5	4.5	-	-
	5.8	1.1	4.4	2.6	-	-
	3.4	0.8	2.8	1.4	-	-
	2.0	0.6	1.5	0.8	-	-
McM J1857b	33.0	-	34.0	16.0	13	35
	16.3	-	11.2	6.9	12	28

Table 10. Whorl dimensions (in mm) and ribbing densities (* number per half-whorl) for *Chondroceras* n. sp. indet. ♀ from MacKenzie Bay, Queen Charlotte Islands. Both specimens are entirely septate.

Suborder PHYLLOCERATINA Arkell, 1950
Family PHYLLOCERATIDAE Zittel, 1884
Subfamily CALLIPHYLLOCERATINAE Spath, 1927
Genus *Calliphylloceras* Spath, 1927

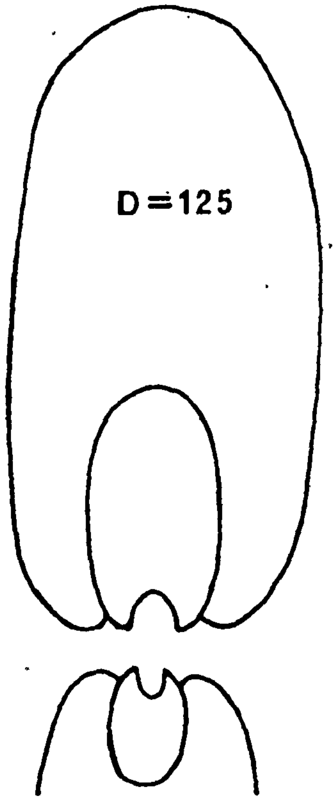
Type Species: *Calliphylloceras disputabile* (Zittel, 1869), by original designation.

Calliphylloceras sp. indet.
(Pl. 8, fig. 7; Text-figs. 74, 75)

Material: Three internal molds, all septate (McM J1826-8), the latter being a large fragment from a shell whose diameter must have exceeded 250 mm. Lower parts of the Yakoun Formation, South Balch Island, Queen Charlotte Islands.

Description: Whorls strongly compressed and much higher than wide (H/W = 1.6-2.0). Venter rounded, flanks smooth and flattened. Umbilicus very narrow (W/D = 0.08 at D = 120 mm) with narrow umbilical walls which are almost vertical and curve strongly onto the flanks.

The internal molds show no sign of ribbing or other ornamentation. There are probably 6-8 faint, narrow, gently sigmoidal constrictions per whorl. Features of the body chamber are unknown.



Text-fig. 74.

Whorl cross-section (phragmocone) of *Calliphylloceras* sp. indet. from South Balch Island. McM J1826, x 1 (approx.).

Text-fig. 75. Part of the external suture of *Calliphylloceras* sp. indet. at D = 110 mm. McM J1826.

Remarks: Phylloceratids comprise relatively small proportions of Bajocian ammonoid faunas at several localities in western North America. *"Macrophylloceras" (= Partschiceras)* and *Holcophylloceras* occur in southern Alaska (Imlay, 1964, pp. B32, 33); *Phylloceras*, *Holcophylloceras* and *Calliphylloceras* in eastern Oregon (Imlay, 1973, pp. 54, 55). They have not so far been recorded from the interior basins of western Alberta, Wyoming, Idaho and Utah.

Four specimens from the upper part of the Weberg Member of the Snowshoe Formation in eastern Oregon (correlated with the "Sowerbyi" Zone) were referred to *Calliphylloceras* by Imlay (1973, p. 54). Very brief descriptions were given and only one small specimen illustrated so that comparisons are not possible.

Geczy (1967) described and figured a large number of species of *Calliphylloceras* from Hungary, mostly from the Lower Jurassic and lower Middle Jurassic. The present species is probably much larger than most figured by Geczy and the constrictions are not as strong as those on the Hungarian species. Whorl proportions are closest to those of *C. connectens frechi* (Prinz) though the flanks of that species are more inflated. *C. liasicum* Geczy has similar whorl dimensions but a smaller degree of whorl overlap and higher rate of whorl expansion.

ORDER NAUTILIDA

Superfamily NAUTILACEAE De Blainville, 1825

Family NAUTILIDAE De Blainville, 1825

Genus *Cenoceras* Hyatt, 1884

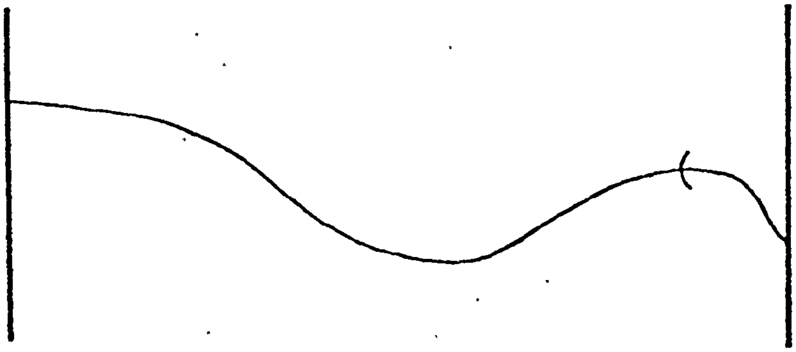
Type Species: *Cenoceras intermedius* (J. Sowerby, 1816), by original designation.

Remarks: *Cenoceras* is the most diverse of the post-Triassic nautiloids, represented by some 97 described species (Kummel, 1956, p. 361) with a cosmopolitan distribution throughout the Lower and Middle Jurassic. However, Jurassic nautiloids have only rarely been recorded from North America: four species representing two genera were described by Kummel (1954) and another two by Castillo and Aguilera (1895). *C. imlayi* (Kummel) is from the Kialagvik Formation of southern Alaska (the Aalenian *E. howelli* Zone of Westermann, 1964c) and *C. lupheri* (Kummel) is from the Weberg Formation of Oregon ("Sowerbyi" Zone).

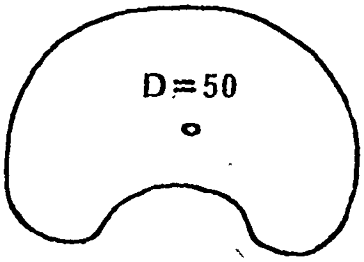
Cenoceras sp. indet.

(Pl. 14, fig. 5; Text-figs. 76, 77)

Material: A single internal mold, wholly septate and about 50 mm in diameter (McM J1825b), from the lower parts of the Yakoun Formation on the north-western shore of South Balch Island, approximately 38 m above the lowest exposure of the Formation on this Island. Another from the lowest exposed strata of the Yakoun Formation at MacKenzie Bay (McM J1881).



Text-fig. 76. Suture line of *Cenoceras* sp. indet. at D = 50 mm (twice natural size). McM J1825b.



Text-fig. 77. Cross-section of ph⁻agmocone whorl of *Cenoceras* sp. indet., McM J1825b, x 1.

Description: Shell globose with a very deep, narrow umbilicus (15% of shell diameter); umbilical wall vertical with a broadly rounded shoulder which is the widest part of the whorl. Flanks only slightly flattened, convergent toward the venter which is broad and somewhat flattened. Whorls depressed, H/W = 0.66 at a diameter of 50 mm. Siphuncle subdorsal; septa concave toward aperture.

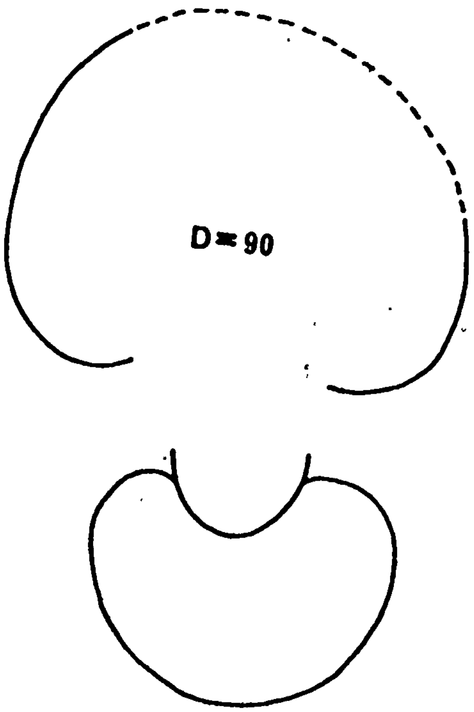
The inner whorls have faint ornamentation preserved in places, consisting of both growth lines and lirae. Suture smooth, straight across the venter with a broad, shallow lateral lobe and a short, narrow V-shaped dorsal lobe (Text-fig. 76).

Remarks: This specimen resembles *C. lupheri* (Kummel) from the Weberg Member of the Snowshoe Formation in eastern Oregon in whorl shape and relative umbilical diameter. Erroneously described as "compressed" by Kummel (1954, p. 323) the whorl section of *C. lupheri* has a H/W ratio of 0.72 at the adoral end of the phragmocone which is very close to that of the present specimen (0.66 at D = 50 mm; Text-fig. 77). However, no shell ornamentation is preserved on the holotype of *C. lupheri*.

Genus *Eutrephoceras* Hyatt, 1894

Type Species: *Eutrephoceras dekayi* (Morton, 1834), by original designation.

Remarks: Morphological distinction between the two large nautiloid stocks represented by *Cenoceras* and *Eutrephoceras* appears difficult to maintain. According to the detailed discussions of Kummel (1956), *Eutrephoceras* has an essentially smooth conch and globose whorl section while *Cenoceras* typically bears fine lirae and growth lines and has a more quadrate whorl section. The name *Cenoceras* is usually given to Upper Triassic-Middle Jurassic forms, while *Eutrephoceras* ranges from the Upper Jurassic to



Text-fig. 78. Cross-section of phragmocone whorls of ?*Eutrephoceras* sp. indet.; McM J1825a, x 1; from the lower parts of the Yakoun Formation, South Balch Island.

Miocene (Kummel, 1964, p. 449). However, the range of whorl shapes illustrated for *Cenoceras* (Pia, 1914; reproduced as Figs. 8, 9 and 10 in Kummel, 1956) clearly includes forms which also appear within the range illustrated for *Eutrephoceras* (Kummel, 1956, Fig. 13). There are specimens from the Cenomanian (Upper Cretaceous) of France in the McMaster University collections (McM K44) which bear fine lirae and growth lines. ?*Eutrephoceras* sp. indet. from the Queen Charlotte Islands, an apparently smooth-shelled form with globose whorl section, is of Lower Bajocian (Middle Jurassic) age.

If ornamentation and whorl shape are used to separate *Cenoceras* and *Eutrephoceras*, then their supposed age difference must be disregarded.

Indeed, Kummel (1954) has already listed several Middle Jurassic species which he considers belong to *Eutrephoceras* (p. 321).

?*Eutrephoceras* sp. indet.

(Pl. 14, fig. 4; Text-fig. 78)

Material: Fully septate, internal mold about 90 mm in diameter, McM J1825a, from the lower part of the Yakoun Formation, about 38 m above the exposed base of the Formation on South Balch Island.

Description: Shell globose with slightly flattened sides converging towards the venter; umbilical shoulder broadly rounded and is the widest part of the whorl (Text-fig. 78). Umbilical wall vertical; umbilicus very narrow (15% of shell diameter). Whorls depressed with H/W = 0.68-0.74. No ornamentation preserved. Position of the siphuncle unknown. Suture with external ventral and lateral lobe, both very broad and shallow; the internal suture is unknown.

Remarks: *E. montanensis* Kummel from the Callovian Rierdon Formation in Montana has much narrower, compressed whorls (H/W = 1.3 vs. 0.68-0.74). Another specimen of *Eutrephoceras* has been recorded from the Bajocian Twin Creek Limestone in Wyoming (Kummel, 1954, p. 321), but it was not described or illustrated.

CHAPTER 9

CONCLUSIONS

The recognition of dimorphism in several genera of stephanoceratid and sphaeroceratid ammonites from the Bajocian rocks of the Queen Charlotte Islands has been based largely on detailed studies of their ontogenetic development. The value of such studies is also emphasised by past misidentification of ammonite genera because only features of one growth stage were observed (either the adult body chamber or incomplete phragmocone whorls). The more complete set of taxonomic characters provided by ontogenetic changes has allowed a more precise understanding of both the phylogeny and taxonomy of these ammonites. Selection of data for statistical testing of growth patterns in supposed dimorphs needs further investigation.

Taxonomic revision of the stephanoceratid ammonites of western North America also permits more detailed faunal zonation of the enclosing sediments. Present comparison of faunal associations and stratigraphic occurrences of ammonites from the Queen Charlotte Islands, southern Alaska, western Alberta and eastern Oregon suggests that the *Zemistephanus* faunas are older than the *Stephanoceras* faunas (belonging to the upper Humphriesianum Subzone) and the former are placed in the lowermost Humphriesianum Zone or the upper Sauzei Zone. Consequently the ages of parts of the Snowshoe Formation and the Basey Member in eastern Oregon and the Fitz Creek Siltstone in southern Alaska need to be revised; they are now placed in the Sauzei Zone.

Detailed stratigraphic subdivisions of Bajocian strata made possible by stephanoceratid ammonites should provide a key to the history of sedimentary basins and dating of major tectonic events throughout little known areas of central and western British Columbia. Further analysis of the stephanoceratid faunas of western Alberta is needed to determine the faunal succession in, and history of, the Fernie Sea during Middle Jurassic time.

APPENDIX 1

Data and Regression Equations for the "mass curves" shown on Text-figures for each taxon. Statistics calculated on measurements from phragmocone whorls only.

* indicates regression co-efficient significantly different from zero at 5% level of significance

** indicates correlation co-efficient significant at 5% level of significance

	Text-fig.	Number of specimens	Number of individual measurements (n =)	Regression Equation	Std. error of slope	Correlation coefficient
Zemistephanus richardsoni (Whiteaves, 1876) ♀ & ♂						
D vs. W ♀ [macroconch]	8	16	67	$Y = 0.67X - 0.54$	.0104*	0.99**
♂ [microconch]	8	5	22	$Y = 0.63X - 0.64$	.019*	0.98**
D vs. H ♀ [macroconch]	9	16	73	$Y = 0.38X - 0.24$	.0056*	0.99**
♂ [microconch]	9	5	22	$Y = 0.34X + 0.02$	.0109*	0.98**
D vs. U ♀ [macroconch]	10	16	66	$Y = 0.36X + 0.35$	.0068*	0.98**
♂ [microconch]	10	5	19	$Y = 0.42X - 0.37$	.017*	0.98**

APPENDIX 1 (cont'd)

	Text-fig.	Number of specimens	Number of individual measurements (n =)	Regression Equation	Std. error of slope	Correlation coefficient
Zemistephanus crickmayi (McLearn, 1927) ♂						
D vs. W ♂ [microconch]	17	13	62	$Y = 0.54X + 0.73$	.011*	0.98**
D vs. H ♂ [microconch]	18	13	62	$Y = 0.35X + 0.04$	.005*	0.99**
D vs. U ♂ [microconch]	19	13	59	$Y = 0.41X - 0.22$	.0057*	0.99**
Stephanoceras itinsae (McLearn, 1927) ♀ & ♂						
D vs. W ♀ [macroconch]	25	13	55	$Y = 0.43X + 4.55$	.0117*	0.97**
♂ [microconch]	25	11	40	$Y = 0.53X + 0.46$	.014*	0.98**
D vs. H ♀ [macroconch]	26	13	55	$Y = 0.31X + 1.22$	.006*	0.98**
♂ [microconch]	26	11	40	$Y = 0.33X + 0.08$	.0057*	0.99**
D vs. U ♀ [macroconch]	27	13	56	$Y = 0.46X - 1.62$	.009*	0.98**
♂ [microconch]	27	11	34	$Y = 0.45X - 0.32$	.01*	0.99**

APPENDIX 1 (cont'd)

	Text-fig.	Number of specimens	Number of individual measurements (n =)	Regression Equation	Std. error of slope	Correlation coefficient
Stephanoceras skidegatense (Whiteaves, 1876) ♀ & ♂						
D vs. W ♀ [macroconch]	34	9	25	$Y = 0.38X + 3.57$	.017*	0.97**
♂ [microconch]	34	2	14	$Y = 0.59X - 0.15$	.016*	0.99**
D vs. H ♀ [macroconch]	35	9	25	$Y = 0.31X + 0.68$	.0086*	0.99**
♂ [microconch]	35	2	14	$Y = 0.38X - 0.35$	.008*	0.99**
D vs. U ♀ [macroconch]	36	9	25	$Y = 0.49X - 1.84$	.010*	0.99**
♂ [microconch]	36	2	11	$Y = 0.42X - 0.12$	.0056*	0.99**
Chondroceras defontii (McLearn, 1927) ♀						
D vs. W ♀ [macroconch]	61	4	8	$Y = 0.76X - 0.17$	.07*	0.96**
D vs. H ♀ [macroconch]	62	4	8	$Y = 0.49X + 0.84$	.029*	0.98**
D vs. U ♀ [macroconch]	63	3	7	$Y = 0.05X + 1.2$	.012*	0.79**

APPENDIX 1 (cont'd)

	Text-fig.	Number of specimens	Number of individual measurements (n =)	Regression Equation	Std. error of slope	Correlation coefficient
Chondroceras oblatum (Whiteaves, 1876) ♀						
D vs. W ♀ [macroconch]	52	4	20	$Y = 0.76X - 0.14$	.02*	0.99**
D vs. H ♀ [macroconch]	53	4	21	$Y = 0.48X + 0.24$	.025*	0.97**
"*Saxitoniceras marshalli*" McLearn, 1927 ♀ [= *Chondroceras oblatum*]						
D vs. W ♀ [macroconch]	52	9	48	$Y = 0.79X - 0.31$	.018*	0.98**
D vs. H ♀ [macroconch]	53	9	48	$Y = 0.51X + 0.03$	.011*	0.98**
D vs. U ♀ [macroconch]	54	8	24	$Y = 0.13X - 0.06$	.01*	0.92**
Chondroceras allani (McLearn, 1927) ♀						
D vs. W ♀ [macroconch]	67	8	46	$Y = 0.69X - 0.05$	.009*	0.99**
D vs. H ♀ [macroconch]	68	8	46	$Y = 0.50X + 0.13$	.006*	0.99**
D vs. U ♀ [macroconch]	69	6	17	$Y = 0.16X - 0.28$	.018*	0.88**

APPENDIX 2

Measurements and data used in formal statistical comparisons of sexual dimorphs. Only measurements from phragmocone whorls were used; there are marked changes in growth ratios at the end of the nepionic whorl and the beginning of the body chamber. A single measurement from each specimen was used (all measurements shown are in mm).

	D	W	H	U
*Zemistephanus richardsoni** (Whiteaves, 1876) ♀ [macroconch]	40.6	27.0	18.5	14.7
	16.0	8.7	5.8	--
	6.4	3.9	2.0	2.9
	24.5	16.7	8.9	9.0
	33.6	21.4	13.0	12.0
	10.4	7.0	3.8	4.0
	8.9	5.7	3.2	3.8
	38.4	23.5	11.8	13.1
	28.7	15.0	10.2	9.1
	21.4	--	--	8.5
*Zemistephanus richardsoni** (Whiteaves, 1876) ♂ [microconch]	6.5	3.5	2.1	2.7
	31.5	20.2	10.5	13.2
	40.5	25.1	14.0	17.4
	21.7	13.0	7.2	--
	16.9	10.0	5.9	6.1
	38.0	--	--	14.0

Regression Analysis for *Zemistephanus richardsoni*

D vs. W ♀ $Y = 0.634X - 0.31$

♂ $Y = 0.646X - 0.776$

(a) Variance: $F = 9.56$ $F_{.05}(8, 4) = 6.04$

hypothesis of equal variances rejected

D vs. H ♀ $Y = 0.396X - 0.56$

♂ $Y = 0.345X - 0.14$

(a) Variance: $F = 97.3$ $F_{.05}(8, 4) = 6.04$

hypothesis of equal variances rejected

D vs. U ♀ $Y = o.329X + 0.77$

♂ $Y = 0.412X - 0.32$

* see p. 229 and following for statistical tests on a second set of data for this species.

APPENDIX 2 (cont'd)

(a) Variance: $F = 3.87$ $F_{.05}(4, 8) = 3.84$

hypothesis of equal variances rejected

W vs. H ♀ $Y = 0.62X - 0.33$

♂ $Y = 0.532X + 0.30$

(a) Variance: $F = 11.65$ $F_{.05}(8, 4) = 6.04$

hypothesis of equal variances rejected

	D	W	H	U
Stephanoceras itinsae	31.0	15.7	9.9	--
(McLearn, 1927) ♀	26.4	15.6	9.1	--
[macroconch]	30.0	17.4	10.5	--
	39.0	19.5	15.5	13.0
	27.4	17.5	10.0	14.4
	34.5	19.0	11.9	15.3
	7.0	4.7	2.6	3.0
	33.8	19.6	12.5	14.6
	25.0	12.7	8.2	10.5
	30.0	--	--	12.2
Stephanoceras itinsae	24.8	13.9	8.6	11.2
(McLearn, 1927) ♂	15.0	9.0	5.0	—
[microconch]	18.7	10.0	5.5	7.3
	21.2	13.4	7.4	9.1
	36.2	20.5	10.7	17.0
	40.6	18.1	13.3	18.2
	30.5	12.4	9.7	14.0
	5.0	2.9	1.5	2.2
	10.0	5.7	3.3	4.2
	29.4	17.2	10.2	13.2

Regression Analysis for *Stephanoceras itinsae*

D vs. W ♀ $Y = 0.496X + 1.75$

♂ $Y = 0.459X + 1.67$

(a) Variance: $F = 1.95$ $F_{.05}(9, 8) = 3.39$

hypothesis of equal variances accepted

APPENDIX 2 (cont'd)

(b) Slopes: $t = -0.445$ $t_{(.05,\ 10)} = 1.753$

hypothesis of equal slopes accepted

(c) Intercepts: $t = 4.76$ $t_{(.05,\ 16)} = 1.746$

hypothesis of equal intercepts rejected

D vs. H ♀ $Y = 0.378X - 0.64$

♂ $Y = 0.319X + 0.13$

(a) Variance: $F = 2.17$ $F_{.05}(8,\ 9) = 3.23$

hypothesis of equal variances accepted

(b) Slopes: $t = 1.79$ $t_{(.05,\ 15)} = 1.753$

hypothesis of equal slopes rejected

(c) Intercepts: $t = 9.02$ $t_{(.05,\ 15)} = 1.753$

hypothesis of equal intercepts rejected

D vs. U ♀ $Y = 0.369X + 1.49$

♂ $Y = 0.469X - 0.58$

(a) Variance: $F = 16.6$ $F_{.05}(6,\ 8) = 3.58$

hypothesis of equal variances rejected

W vs. H ♀ $Y = 0.706X - 1.09$

♂ $Y = 0.621X - 0.13$

(a) Variance: $F = 1.1$ $F_{.05}(9,\ 8) = 3.39$

hypothesis of equal variances accepted

(b) Slopes: $t = 0.016$ $t_{(.05,\ 15)} = 1.753$

hypothesis of equal slopes accepted

(c) Intercepts: $t = 1.5$ $t_{(.05,\ 15)} = 1.753$

hypothesis of equal intercepts accepted

APPENDIX 2 (cont'd)

	D	W	H	U
Stephanoceras skidegatense	43.5	18.5	16.3	18.2
(Whiteaves, 1876) ♀	20.6	10.5	7.3	7.5
[macroconch]	33.7	19.2	13.2	13.7
	32.7	16.0	11.7	16.4
	15.0	9.0	4.4	7.5
	35.3	19.8	12.2	13.7
	30.5	14.3	9.3	11.4
Stephanoceras skidegatense	36.5	23.0	14.0	15.0
(Whiteaves, 1876) ♂	14.2	7.6	4.2	--
[microconch]	43.4	--	--	18.6

Regression Analysis for *Stephanoceras skidegatense*

D vs. W ♀ $Y = 0.41X + 3.0$

♂ $Y = 0.69X - 2.2$

(a) Variance: $F = 3.8$ $F_{.05}(6, 1) = 234.0$

accept hypothesis of equal variances

(b) Slopes: $t = 1.89$ $t_{(.05,\ 5)} = 2.015$

accept hypothesis of equal slopes

(c) Intercepts: $t = 1.65$ $t_{(.05,\ 6)} = 1.943$

accept hypothesis of equal intercepts

D vs. H ♀ $Y = 0.41X - 1.64$

♂ $Y = 0.44X - 2.0$

(a) Variance: $F = 0.8$ $F_{.05}(6, 1) = 234.0$

accept hypothesis of equal variances

(b) Slopes: $t = 0.44$ $t_{(.05,\ 5)} = 2.015$

accept hypothesis of equal slopes

(c) Intercepts: $t = 0.642$ $t_{(.05,\ 6)} = 1.943$

accept hypothesis of equal intercepts

APPENDIX 2 (cont'd)

D vs. U ♀ $Y = 0.40X + 0.46$

♂ $Y = 0.52X - 4.0$

(a) Variance: $F = 4.6$ $F_{.05}(6, 1) = 234.0$

accept hypothesis of equal variance

(b) Slopes: $t = 0.356$ $t_{(.05, 5)} = 2.015$

accept hypothesis of equal slopes

(c) Intercepts: $t = 8.3$ $t_{(.05, 6)} = 1.943$

reject hypothesis of equal intercepts

W vs. H ♀ $Y = 0.84X - 2.28$

♂ $Y = 0.64X - 0.6$

(a) Variance: $F = 3.2$ $F_{.05}(6, 1) = 234.0$

accept hypothesis of equal variances

(b) Slopes: $t = 0.87$ $t_{(.05, 5)} = 2.015$

accept hypothesis of equal slopes

(c) Intercepts: $t = 0.608$ $t_{(.05, 6)} = 1.943$

accept hypothesis of equal intercepts

	D	W	H
Chondroceras oblatum (Whiteaves, 1876) ♀ [macroconch]	37.0	30.0	20.9
	10.0	8.3	5.7
	6.2	4.3	3.3
	23.4	19.2	11.7
"*Saxitoniceras marshalli*" McLearn, 1927 ♀ [= *C. oblatum*] [macroconch]	34.3	34.0	17.5
	40.8	28.7	20.8
	35.6	29.2	19.8
	24.8	19.3	12.0
	2.6	1.7	1.0
	31.8	28.8	14.0
	15.4	12.2	7.5
	10.9	8.8	5.7
	7.0	5.0	3.5
	5.4	4.2	2.8

APPENDIX 2 (cont'd)

Regression Analysis for *Chondroceras oblatum* and *"Saxitonieeras marshalli"*

D vs. W *(C. oblatum)* $Y = 0.825X - 0.35$

(S. marshalli) $Y = 0.839X - 0.32$

(a) Variance: $F = 26.9$ $F_{.05}(9, 3) = 8.84$

reject hypothesis of equal variances

D vs. H *(C. oblatum)* $Y = 0.557X - 0.27$

(S. marshalli) $Y = 0.51X - 0.22$

(a) Variance: $F = 0.944$ $F_{.05}(9, 3) = 8.84$

accept hypothesis of equal variances

(b) Slopes: $t = 1.02$ $t_{(.05,\ 10)} = 1.812$

accept hypothesis of equal slopes

(c) Intercepts: $t = 1.33$ $t_{(.05,\ 11)} = 1.796$

accept hypothesis of equal intercepts

W vs. H *(C. oblatum)* $Y = 0.674X - 0.013$

(S. marshalli) $Y = 0.577X + 0.54$

(a) Variance: $F = 4.18$ $F_{.05}(9, 3) = 8.84$

accept hypothesis of equal variances

(b) Slopes: $t = 0.86$ $t_{(.05,\ 10)} = 1.812$

accept hypothesis of equal slopes

(c) Intercepts: $t = 0.817$ $t_{(.05,\ 11)} = 1.796$

accept hypothesis of equal intercepts

APPENDIX 2 (cont'd)

	D	W	H
"Saxitoniceras marshalli"	34.3	34.0	17.5
McLearn, 1927 ♀	40.8	28.7	20.8
[= *C. oblatum*]	35.6	29.3	19.8
[macroconch]	24.8	19.3	12.0
	2.6	1.7	1.0
	31.8	18.8	14.0
	15.4	12.2	7.5
	10.9	8.8	5.7
	7.0	5.0	3.5
	5.4	4.2	2.8
Chondroceras allani	26.0	17.6	13.8
(McLearn, 1927) ♀	37.0	24.9	18.2
[macroconch]	12.8	8.9	7.0
	18.7	15.0	9.4
	10.0	7.5	6.4
	4.5	2.9	2.3
	7.5	5.1	3.8
	25.0	17.2	12.4

Regression Analysis for *"Saxitoniceras marshalli"* and *Chondroceras allani*

D vs. W (*S. marshalli*) $Y = 0.839X - 0.32$

(*C. allani*) $Y = 0.673X + 0.487$

(a) Variance: $F = 4.96$ $F_{.05}(9, 7) = 3.68$

reject hypothesis of equal variances

D vs. H (*S. marshalli*) $Y = 0.51X - 0.22$

(*C. allani*) $Y = 0.483X + 0.62$

(a) Variance: $F = 0.71$ $F_{.05}(9, 7) = 3.68$

accept hypothesis of equal variances

(b) Slopes: $t = 0.16$ $t_{(.05,\ 14)} = 1.761$

accept hypothesis of equal slopes

(c) Intercepts: $t = 0.578$ $t_{(.05,\ 15)} = 1.753$

accept hypothesis of equal intercepts

APPENDIX 2 (cont'd)

W vs. H (*S. marshalli*) $Y = 0.577X + 0.54$

([illegible]) $Y = 0.71X + 0.37$

(a) Variance: $F = 2.93$ $F_{.05}(9, 7) = 2.93$

accept hypothesis of equal variances

(b) Slopes: $t = 1.37$ $t_{(.05, 14)} = 1.761$

accept hypothesis of equal slopes

(c) Intercepts: $t = 1.84$ $t_{(.05, 15)} = 1.753$

reject hypothesis of equal intercepts

	D	W	H	U
Zemistephanus richardsoni	44.0	30.0	18.5	17.0
(Whiteaves, 1876) ♀	48.0	34.0	17.0	19.8
[macroconch]	29.5	16.4	11.2	10.0
	17.7	10.3	7.0	6.4
	11.3	6.5	3.4	---
	5.4	3.4	1.9	---
	3.9	3.0	1.4	1.3
	12.0	6.9	3.5	5.0
	41.6	27.0	15.2	15.0
	38.3	23.0	13.5	12.9
Zemistephanus richardsoni	8.7	4.6	2.8	3.6
(Whiteaves, 1876) ♂	21.6	11.9	7.4	6.7
[microconch]	35.5	23.5	12.3	14.0
	28.5	18.0	10.3	---
	37.1	22.5	12.6	14.3

Regression Analysis for *Zemistephanus richardsoni*

D vs. W ♀ $Y = 0.679X - 1.06$

♂ $Y = 0.675X - 1.658$

(a) Variance: $F = 2.21$ $F_{.05}(9, 4) = 6.0$

hypothesis of equal variances accepted

(b) Slopes: $t = 0.06$ $t_{(.05,\ 11)} = 1.796$

hypothesis of equal slopes accepted

(c) Intercepts: $t = 25.33$ $t_{(.05,\ 12)} = 1.782$

hypothesis of equal intercepts rejected

D. vs. H ♀ $Y = 0.383X - 0.4$

♂ $Y = 0.351X - 0.14$

(a) Variance: $F = 9.1$ $F_{.05}(9,\ 4) = 6.0$

hypothesis of equal variances rejected

D vs. U ♀ $Y = 0.385X - 0.38$

♂ $Y = 0.395X - 0.53$

(a) Variance: $F = 1.06$ $F_{.05}(7,\ 3) = 8.89$

hypothesis of equal variances accepted

(b) Slopes: $t = 0.17$ $t_{(.05,\ 8)} = 1.86$

hypothesis of equal slopes accepted

(c) Intercepts: $t = 2.0$ $t_{(.05,\ 9)} = 1.833$

hypothesis of equal intercepts rejected

W vs. H ♀ $Y = 0.556X + 0.334$

♂ $Y = 0.513X + 0.814$

(a) Variance: $F = 5.81$ $F_{.05}(9,\ 4) = 6.0$

hypothesis of equal variances accepted

(b) Slopes: $t = 0.4$ $t_{(.05,\ 11)} = 1.796$

hypothesis of equal slopes accepted

(c) Intercepts: $t = 10.5$ $t_{(.05,\ 12)} = 1.782$

hypothesis of equal intercepts rejected

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PLATES 1 - 14
WITH EXPLANATIONS

EXPLANATION OF PLATE 1

[Position of last septum indicated by ▶; all figures natural size unless otherwise indicated]

Figs. 1-6. *Zemistephanus richardsoni* (Whiteaves) ♀ [macroconch]

1. Complete specimen with aperture, lateral view. Note egression of body chamber, smooth body chamber whorl with large, rounded nodes, deep umbilicus. McM J1797a, x 0.5; from 2 m above the exposed base of the Yakoun Formation at MacKenzie Bay, Queen Charlotte Islands.

2. Almost complete specimen, lateral view. Note egression of body chamber, loss of ribbing on body chamber, deep umbilicus and large, conical nodes on phragmocone whorls. McM J1797d, x 0.5; from 2 m above the exposed base of the Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands.

3. Lateral view. McM J1797c, x 0.5; from 2 m above the exposed base of the Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands.

4a-c. McM J1797b, all x 1; from 2 m above the exposed base of the Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. (a) phragmocone, ventral view at D = 50 mm; (b) phragmocone, ventral view at D = 63 mm; (c) phragmocone, lateral view at D = 63 mm.

5. Phragmocone, ventral view at D = 35 mm. USGS Mesoz. loc. 26599.1, x 1; from 200-300 ft above base of Fitz Creek Siltstone, southern Alaska.

6a-c. USGS Mesoz. loc. 2999.3, all x 1; float specimen from 100-150 ft below top of Fitz Creek Siltstone, southern Alaska. (a) phragmocone, ventral view at D = 18 mm; (b) phragmocone, lateral view at D = 25 mm; (c) phragmocone, ventral view at D = 25 mm.

PLATE 1


1


2


4c


3


5


6a


4a


4b


6b


6c

EXPLANATION OF PLATE 2

[All figures natural size unless otherwise indicated]

Figs. 1-3. *Zemistephanus richardsoni* (Whiteaves) ♂ [microconch]

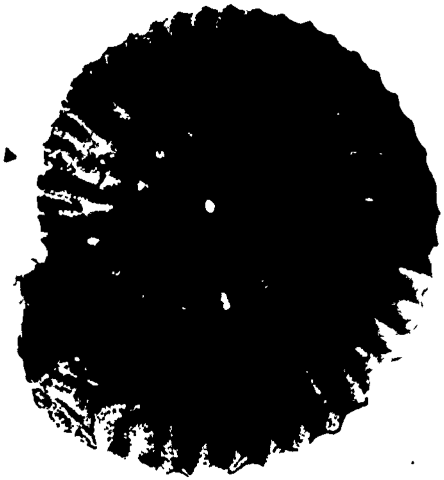
1a-e. McM J1796a (allotype), all x 1; from 2 m above exposed base of Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. (a) lateral view with ventro-lateral lappet; (b) ventral view of body chamber; (c) ventral view at position of last septum at D = 45 mm; (d), (e) lateral and ventral views, phragmocone, at D = 40 mm. Note strong egression of body chamber, persistence of strong ribbing but loss of nodes on body chamber; straight primary ribs and large, conical nodes on phragmocone whorls; decline in density of secondary ribbing from phragmocone to body chamber.

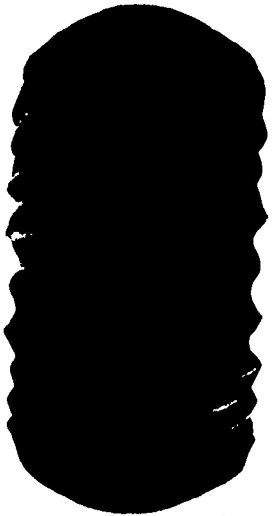
2a, b. GSC 48593, both x 1; Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. (a) lateral view, phragmocone with quarter-whorl of body chamber and fragment of aperture with lappet in approximate position of attachment; (b) ventral view, phragmocone. Note large, conical nodes and strong ribbing.

3. McM J1796b, x 1; phragmocone at D = 40 mm, ventral view; from 2 m above exposed base of Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands.

4. McM J1796c, x 1; from 2 m above exposed base of Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. Parts of phragmocone and body chamber with lappet, lateral view.

PLATE 2


1a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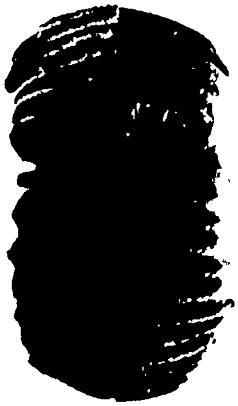
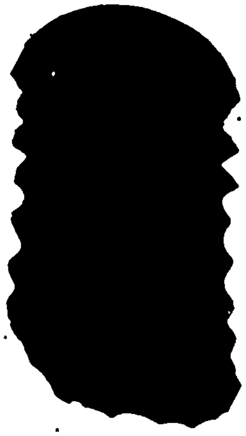
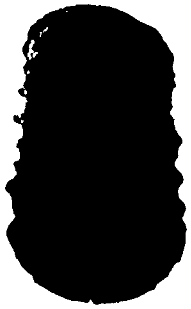

1c


2a


1d


1e


2b


3


4

EXPLANATION OF PLATE 3

[All figures natural size unless otherwise indicated]

Figs. 1-5. *Zemistephanus crickmayi* (McLearn) ♂ [microconch]

1a-d. USGS Mesoz. loc. 2999.4 , all x 1; float from 100-150 ft below top of Fitz Creek Siltstone, southern Alaska. (a) phragmocone, lateral view at D = 37 mm; (b) phragmocone, ventral view at D = 37 mm; (c) lateral view at D = 17 mm; (d) ventral view at D = 17 mm.

2a, b. McM J1798a, both x 1; from 2 m above exposed base of Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. (a) lateral view, phragmocone with small part of body chamber attached; (b) ventral view.

3. McM J1798e, x 1; from 2 m above the exposed base of the Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. Ventral view of body chamber showing strong secondary ribs.

4. McM J1798f, x 1; from 2 m above the exposed base of the Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. Parts of phragmocone and body chamber, lateral view.

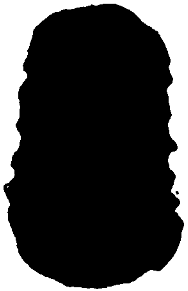
5. McM J1798d, x 1; from 2 m above the exposed base of the Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. Ventral view of the body chamber.

Fig. 6. *Zemistephanus alaskensis* n. sp. ♀ [macroconch]

6a, b. McM J1858a, both x 1; from 30 m above the exposed base of the Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. (a) lateral view, phragmocone and almost one whorl of body chamber; (b) ventral view of body chamber. Note large, conical nodes on phragmocone whorls and broad primary ribs.

PLATE 3


1a

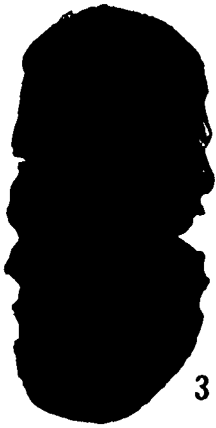

1b


2a


2b


1c


1d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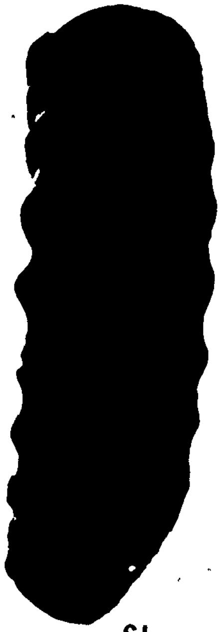
4


6a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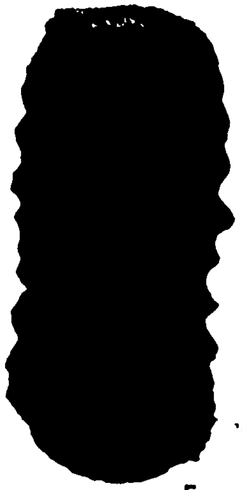
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EXPLANATION OF PLATE 4

[All figures natural size unless otherwise indicated]

Figs. 1-4. *Stephanoceras itinsae* (McLearn) ♀ [macroconch]

1. GSC 13634, x 0.5; from the Yakoun Formation, South Balch Island, Queen Charlotte Islands. Almost complete specimen with most of body chamber showing aperture, lateral view.

2. GSC 40985, x 0.5; from the Yakoun Formation, Reef Island, Queen Charlotte Islands. Complete specimen with aperture, lateral view.

3. GSC 44711, x 0.5; from the Yakoun Formation, South Balch Island, Queen Charlotte Islands. Complete body chamber with aperture, lateral view.

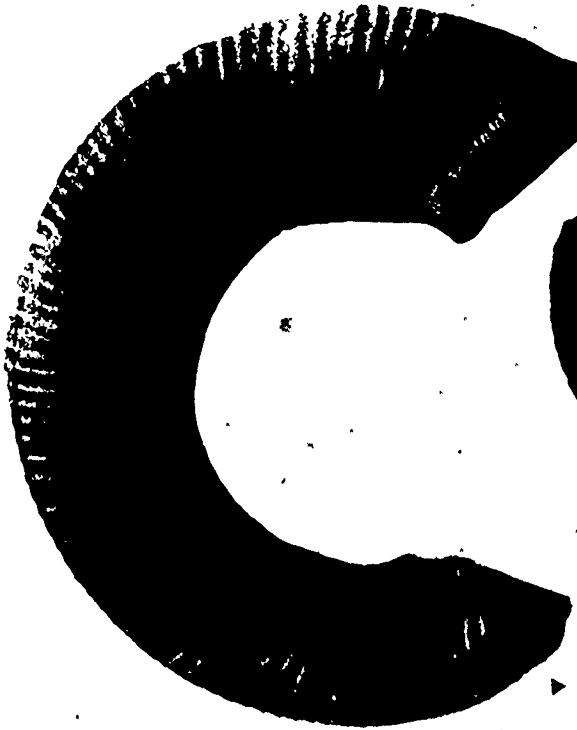
4. GSC 13634, x 0.5; from the Yakoun Formation, South Balch Island, Queen Charlotte Islands. Almost complete specimen, lateral view.

Note the loss of nodes on the body chamber whorl.

PLATE 4


1


2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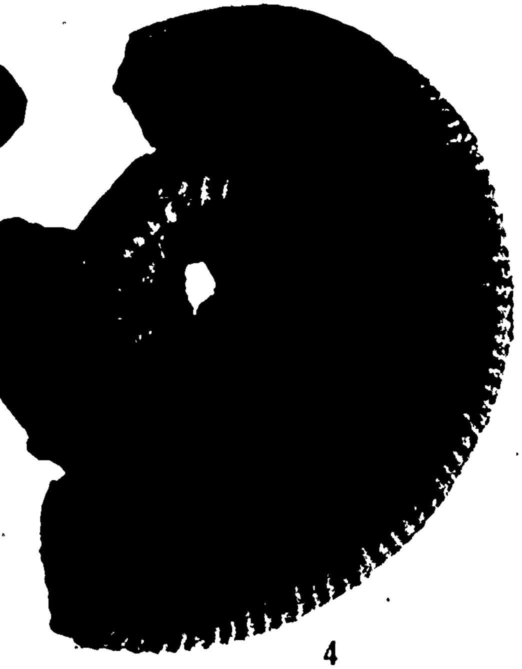
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EXPLANATION OF PLATE 5

[All figures natural size unless otherwise indicated]

Figs. 1-4. *Stephanoceras itinsae* (McLearn) ♀ [macroconch]

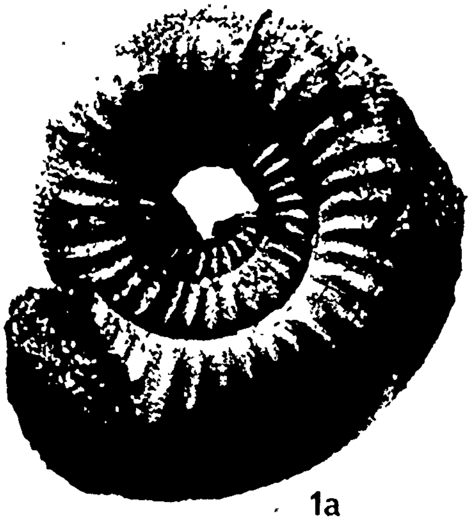
1a-d. Unnumbered specimen, UBC; from Yakoun Formation, "Harty's Island", Queen Charlotte Islands. (a) phragmocone, lateral view, x 0.5; (b) phragmocone, ventral view, x 0.5; (c) phragmocone, ventral view at D = 30 mm, x 1; (d) phragmocone at D = 30 mm, lateral view, x 1.

2. GSC 40985, x 0.5; from the Yakoun Formation, Reef Island, Queen Charlotte Islands. Phragmocone and half-whorl of body chamber, lateral view. Note egression of body chamber.

3a, b. GSC 48601, both x 0.5; from the Yakoun Formation, South Balch Island, Queen Charlotte Islands. (a) phragmocone and half-whorl of body chamber, lateral view; (b) body chamber, ventral view.

4a, b. McM J1808g, both x 1; from undifferentiated Yakoun Formation, eastern shore of South Balch Island, Queen Charlotte Islands. (a) phragmocone, lateral view; (b) phragmocone, ventral view.

PLATE 5


1a

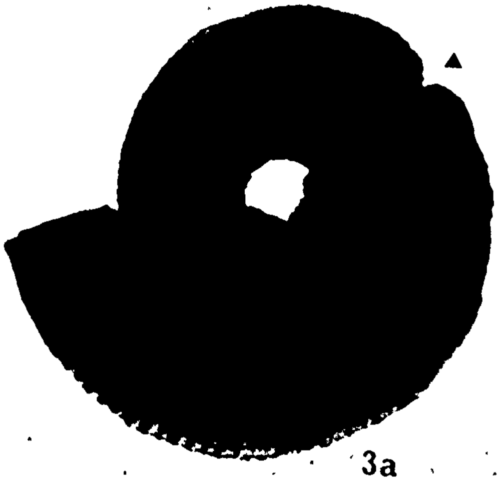

1b


1c


1d


2


4a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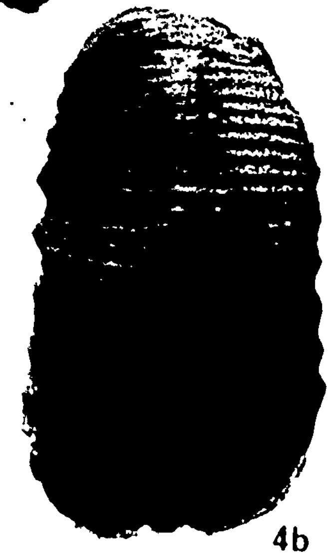
3b


4b

EXPLANATION OF PLATE 6

[All figures natural size unless otherwise indicated]

Fig. 1. *Stephanoceras itinsae* (McLearn) ♀ [macroconch]

1a, b. McM J1880, x 1; from Rock Creek Member, Fernie Group, at Ribbon Creek, southern Alberta. (a) phragmocone, lateral view; (b) ventral view.

Figs. 2-6. *Stephanoceras itinsae* (McLearn) ♂ [microconch]

2. Complete specimen showing body chamber and lappet; lateral view. GSC 48601, x 1; from the Yakoun Formation, South Balch Island , Queen Charlotte Islands.

3. Almost complete specimen with lappet, lateral view. Note forward inclination of primary ribs on inner whorls. GSC 48601, x 1; from the Yakoun Formation, South Balch Island, Queen Charlotte Islands.

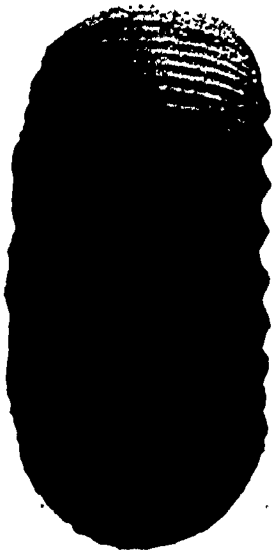
4a-f. McM J1799a, all x 1; from the Yakoun Formation, South Balch Island, Queen Charlotte Islands.
(a) complete specimen showing lappet, lateral view;
(b) ventral view of body chamber; (c), (d) lateral and ventral views at D = 35 mm, adoral end of phragmocone;
(e), (f) lateral and ventral views at D = 30 mm.

5. McM J1801b, x 1; from 40 m above the exposed base of the Yakoun Formation, South Balch Island, Queen Charlotte Islands. Aperture showing lateral lappet.

6a-c. McM J1800, x 1; from 6 m above the exposed base of the Yakoun Formation, South Balch Island, Queen Charlotte Islands. (a) part of complete specimen showing lappet, lateral view; (b) ventral view of body chamber;
(c) ventral view of phragmocone at D = 28 mm.

PLATE 6

1a



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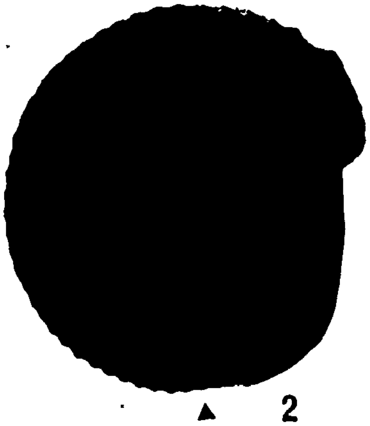

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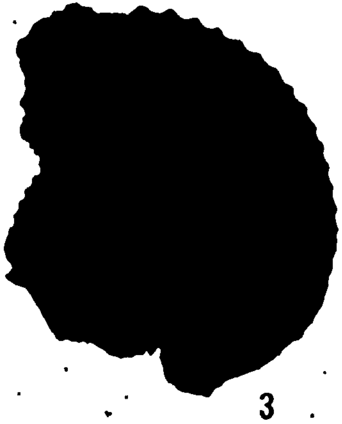
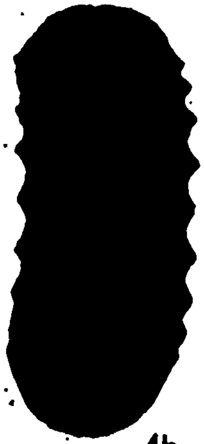


3

4a



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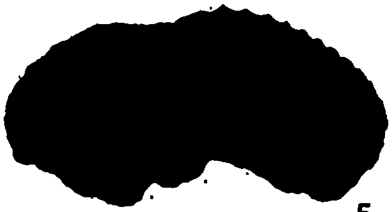

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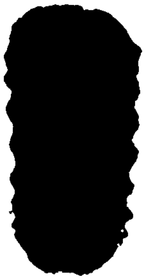
4c



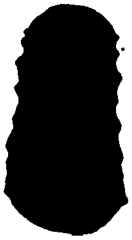
4d

4e

4f

6a

6b



6c

EXPLANATION OF PLATE 7

[All figures natural size unless otherwise indicated]

Fig. 1. *Stephanoceras itinsae* (McLearn) ♂ [microconch]

1a, b. McM J1838, x 1; from the Rock Creek Member, Fernie Group, at Ribbon Creek, southern Alberta. (a) complete body chamber with lappet, lateral view; (b) ventral view of body chamber showing lappet.

Figs. 2, 3. *Stephanoceras skidegatense* (Whiteaves) ♀ [macroconch]

2a, b. McM J1878, x 0.5; from 20 m above the base of the exposed Yakoun Formation at Richardson Bay, Queen Charlotte Islands. (a) part of the body chamber and phragmocone, lateral view; (b) ventral view of body chamber. Note strong, sharp secondary ribs with only two to each primary rib on body chamber.

3. GSC 48594, x 0.5; from the Yakoun Formation, Richardson Bay, Queen Charlotte Islands. Phragmocone, lateral view.

Figs. 4, 5. *Stephanoceras skidegatense* (Whiteaves) juv.

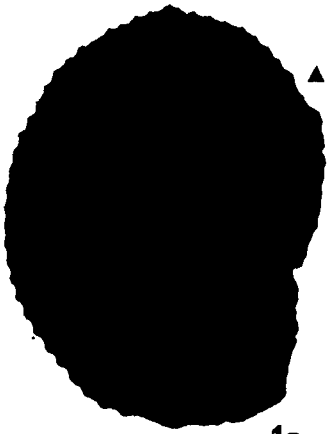
4a, b. GSC 13636, x 2; from the Yakoun Formation, supposedly between MacKenzie Bay and Clapp Bay, Queen Charlotte Islands. (a), (b) lateral and ventral views.

5a, b. McM J1802f, x 2; from 20 m above the exposed base of the Yakoun Formation, Richardson Bay, Queen Charlotte Islands. (a), (b) lateral and ventral views.

Fig. 6. *Stephanoceras skidegatense* (Whiteaves) ♂ [microconch]

6a–c. McM J1802b (allotype), x 1; from 20 m above the exposed base of the Yakoun Formation, Richardson Bay, Queen Charlotte Islands. (a) complete specimen with beginning of lappet, lateral view; (b) ventral view of body chamber; (c) phragmocone, ventral view at D = 30 mm.

PLATE 7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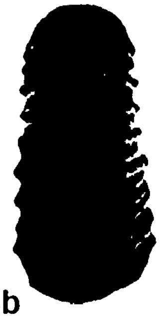
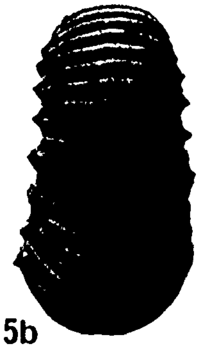
1b


4a


4b


5a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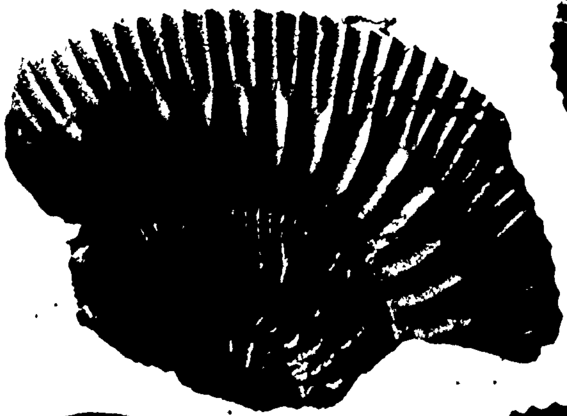

2a


3


2b


6a


6c


6b

EXPLANATION OF PLATE 8

[All figures natural size unless otherwise indicated]

Fig. 1. *Stephanoceras skidegatense* (Whiteaves) ♂ [microconch]

1a-c. McM J1802a, all x 1; from 20 m above the exposed base of the Yakoun Formation, Richardson Bay, Queen Charlotte Islands. (a) ventral view of body chamber; (b), (c) lateral and ventral views of phragmocone at D = 35 mm.

Figs. 2, 3. *Stephanoceras* sp. ♂ aff. *S. skidegatense* (Whiteaves) ♂ [microconch]

2a, b. McM J1804, x 1; from 8 m above the exposed base of the Yakoun Formation, Richardson Bay, Queen Charlotte Islands. (a) ventral view of body chamber; (b) part of phragmocone and body chamber, lateral view.

3a, b. McM J1806, x 1; from 3 m above base of exposed Yakoun Formation, Richardson Bay, Queen Charlotte Islands. (a) ventral view of phragmocone at D = 40 mm; (b) phragmocone, lateral view.

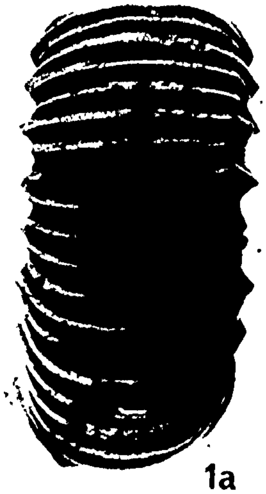
Fig. 4. Stephanoceratidae gen. et sp. indet. B ?♀ [macroconch]
McM J 858, x 0.5; from the Yakoun Formation, MacKenzie Bay, Queen Charlotte Islands. Parts of the phragmocone and body chamber, lateral view. Note broad, flat venter.

Fig. 5. Stephanoceratidae gen. et sp. indet. C ?♀. [macroconch]
McM J1861, x 1; from 10-15 m above the base of the exposed Yakoun Formation at MacKenzie Bay, Queen Charlotte Islands. Phragmocone, lateral view. Note broad, flat venter and lateral shoulder.

Fig. 6. Stephanoceratidae gen. et sp. indet. A.
McM J1860, x 1; from 10-15 m above the base of the exposed Yakoun Formation at MacKenzie Bay, Queen Charlotte Islands. Lateral view. Note very strong secondary ribs and broad, flat venter.

Fig. 7. *Calliphylloceras* sp. indet.
McM J1826, x 0.5; from the lower part of the Yakoun Formation, South Balch Island, Queen Charlotte Islands. (a) phragmocone, ventral view; (b) lateral view.

PLATE 8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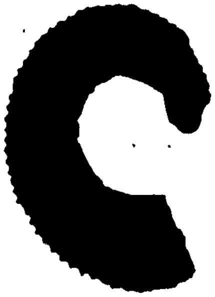
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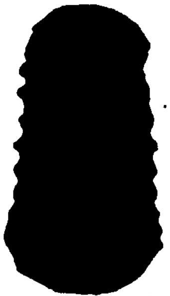
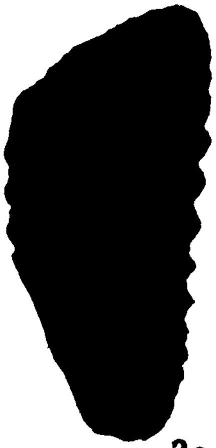

1c


3a


3b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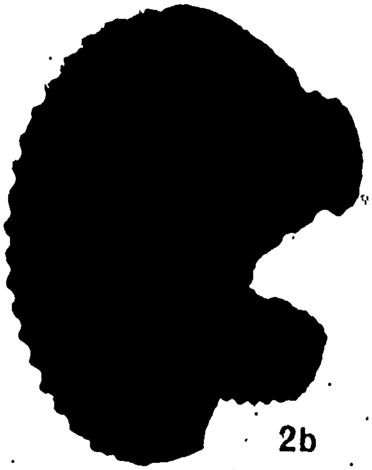
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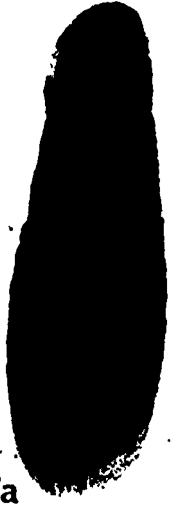

7a


4


5


6


7b

EXPLANATION OF PLATE 9

[All figures natural size unless otherwise indicated]

Fig. 1. *Stephanoceras* sp. aff. *S. kirschneri* Imlay ♀ [macroconch]

1a, b. GA 1035a, both x 0.5; from the collection of Mr F. Garcia, E. N. A. P. (Inst. Geol., Univ. Nac., Santiago) and referred to in Westermann and Riccardi (1972a, p. 20). Salar de Pedernales, Atacama Province, Chile. (a) lateral view showing short, straight primary ribs, round tubercles and fine secondary ribbing; (b) ventral view.

Fig. 2. Stephanoceratidae gen. et sp. indet. E [*?Cadomites*]

1a, b. McM J17791, x 1; from Caracoles, Antofagasta Province, Chile. (a) phragmocone, ventral view, showing dense secondary ribs and prominent, round tubercles; (b) lateral view showing last half-whorl of phragmocone, round tubercles and fine secondary ribbing.

Fig. 3. *Stephanoceras (Skirroceras)* cf. *macrum* (Quenstedt) ♀ [macroconch]

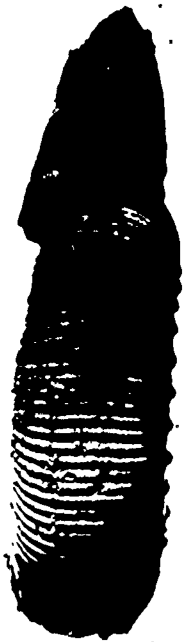
3a, b. McM J1323a, x 1; from the Lajas Formation, Chacaico, Neuquén Province, Argentina (referred to in Westermann and Riccardi, 1972a, p. 10). (a) lateral view; note strong, dense secondary ribs on inner whorl and prominent tubercles. (b) ventral view of ?body chamber.

Fig. 4. *Stephanoceras* n. sp. juv.

4a, b. GA 1035c, both x 1; from the collection of Mr F. Garcia, E. N. A. P. (Inst. Geol. Univ. Nac., Santiago) and mentioned in Westermann and Riccardi (1972a, p. 20). Salar de Pedernales, Atacama Province, Chile. (a) phragmocone, lateral view, showing fine primary ribs and large, round tubercles; (b) ventral view showing broad, gently arched venter.

PLATE 9

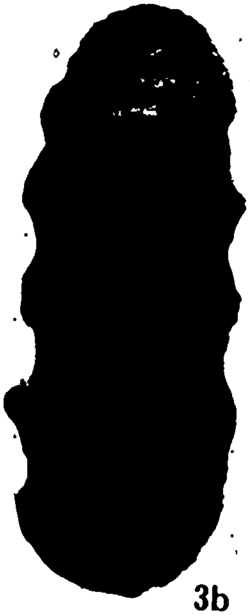

1a


1b


2a


2b


3a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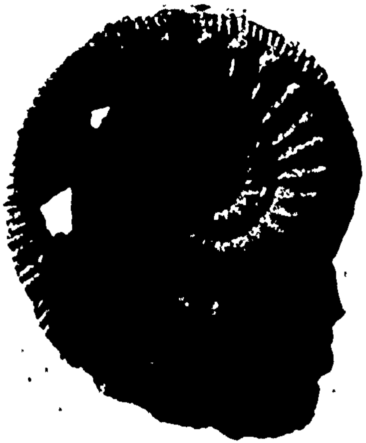

4a


4b

EXPLANATION OF PLATE 10

[All figures natural size unless otherwise indicated]

Fig. 1. *Stephanoceras* sp. aff. *S. caamanoi* McLearn ♀ [macroconch]

1a, b. McM J1779k, both x 1; from Agua Dulce, Caracoles, Antofagasta Province, Chile, upper part of "*Stephanoceras* beds." (a) phragmocone, lateral view showing fine, curved primary ribs and sharp tubercles; (b) ventral view.

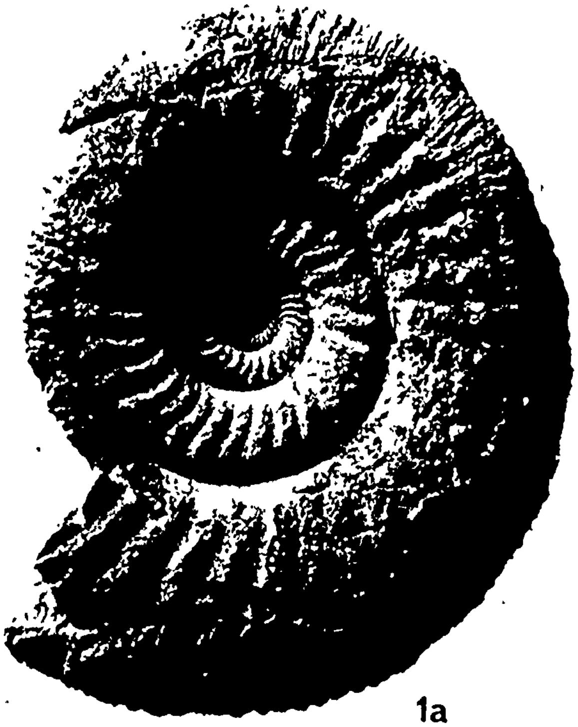
Fig. 2. *Stephanoceras* sp. aff. *S. kirschneri* Imlay ♀ [macroconch]

2. GA 1035b, x 1; from the collection of Mr F. Garcia, E. N. A. P. (Inst. Geol., Univ. Nac., Santiago) and referred to in Westermann and Riccardi (1972a, p. 20). Salar de Pedernales, Atacama Province, Chile. Ventral view.

Fig. 3. *Stephanoceras* n. sp. indet. ♀ [macroconch]

3a, b. McM J1779b, both x 0.5; from Caracoles, Antofagasta Province, Chile. (a) lateral view showing long, thin, curved primary ribs and dense secondary ribs; (b) ventral view.

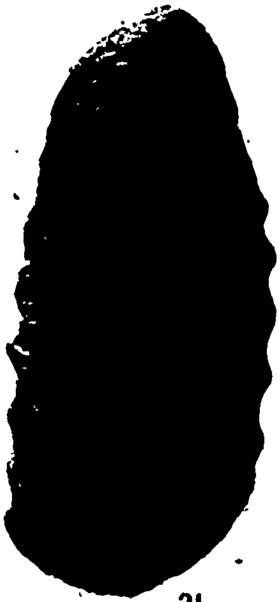
PLATE 10


1a


1b


2


3a


3b

EXPLANATION OF PLATE 11

[All figures natural size unless otherwise indicated]

Fig. 1. *Stephanoceras* n. sp. indet. ♀ [macroconch]

1. McM J1777b, x 0.5; from Caracoles, Antofagasta Province, Chile. Lateral view of phragmocone showing long, curved primary ribs and fine secondary ribbing.

Fig. 2. Stephanoceratidae gen. et sp. indet. D [*?Cadomites*]

2a, b. McM J1777g, both x 1; from Caracoles, Antofagasta Province, Chile. (a) phragmocone, lateral view showing broad, widely spaced primary ribs, large tubercles and strong secondary ribs; (b) ventral view showing strong secondary ribbing and large tubercles.

Fig. 3. *?Teloceras* sp. indet.

3. McM J1295, x 0.5; from Caracoles, Antofagasta Province, Chile. Phragmocone, lateral view showing primary ribs with large, round nodes along the lateral shoulder and gently arched venter.

Fig. 4. *?Epalxites* sp. indet. ♂ [microconch]

4a, b. GA 1035d, both x 1. From the collection of Mr F. Garcia, E. N. A. P. (Inst. Geol., Univ. Nac., Santiago); referred to in Westermann and Riccardi (1972a, p. 20). Salar de Pedernales, Atacama Province, Chile.
(a) ventral view at position of last septum showing broad, slightly arched venter and sharp nodes;
(b) lateral view showing curved primary ribs, large round nodes along lateral shoulder and broad venter; part of crushed lappet also visible at lower left.

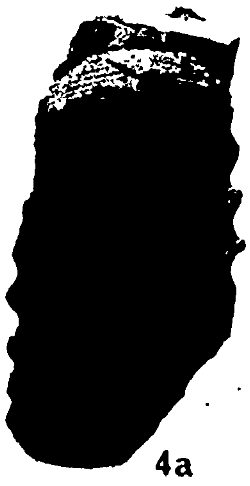
PLATE 11

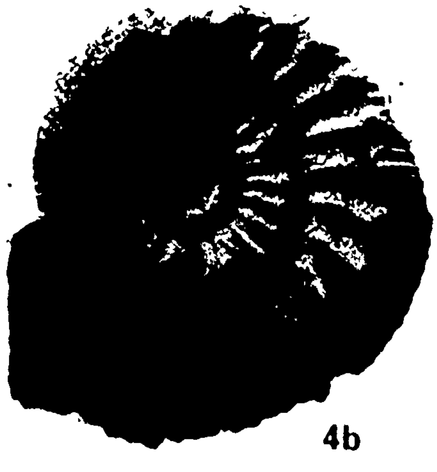

1


2a


2b


3


4a


4b

EXPLANATION OF PLATE 12

[All figures natural size unless otherwise indicated]

Figs. 1-7. *Chondroceras oblatum* (Whiteaves) ♀ [macroconch]

1. McM J1834a, x 1; from 1-3 m above the base of the Yakoun Formation exposed on South Balch Island, Queen Charlotte Islands. Complete, laterally crushed specimen, lateral view. Note constriction and smooth lip at aperture.

2. McM J1832a, x 1; from 44 m above the base of the Yakoun Formation exposed on South Balch Island, Queen Charlotte Islands. Ventral view of body chamber.

3. McM J1832b, x 1; from 44 m above the base of the Yakoun Formation exposed on South Balch Island, Queen Charlotte Islands. Lateral view of phragmocone.

4a, b. McM J1877, x 2; from undifferentiated Yakoun Formation, eastern shore of South Balch Island, Queen Charlotte Islands. (a) phragmocone, lateral view; (b) ventral view.

5a, b. McM J1795; from undifferentiated Yakoun Formation on eastern shore of South Balch Island, Queen Charlotte Islands. (a) phragmocone, ventral view at D = 31 mm; x 1; (b) ventral view at D = 18 mm; x 2.

6a, b. McM J1836c, both x 1; from Rock Creek Member, Fernie Group, Ribbon Creek, southern Alberta. (a) almost complete specimen, lateral view; (b) ventral view of body chamber. Note sudden egression of body chamber.

7a, b. McM J1836b, x 1; from the Rock Creek Member, Fernie Group, Ribbon Creek, southern Alberta. (a) ventral view of body chamber; (b) lateral view, complete specimen.

Figs. 8, 9. *Chondroceras oblatum* (Whiteaves) ♂ [microconch]

8. Allotype, McM J1794a, x 2; from undifferentiated Yakoun Formation, eastern shore, South Balch Island, Queen Charlotte Islands. Complete specimen, lateral view.

9. McM J1835, x 2; from 44 m above base of Yakoun Formation exposed on South Balch Island, Queen Charlotte Islands. Complete specimen, lateral view.

PLATE 12


1


2


3


4a


4b


5a


5b

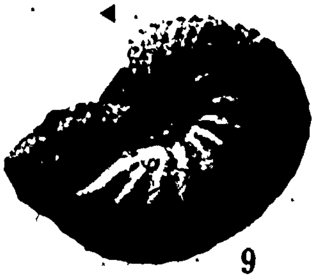

6a


7a


7b


6b


8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EXPLANATION OF PLATE 13

[All figures natural size unless otherwise indicated]

Figs. 1-6. *Chondroceras defontii* (McLearn) ♀ [macroconch]

1a, b. GSC 48594, x 1; Yakoun Formation, Richardson Bay, Queen Charlotte Islands. (a) complete specimen with aperture, lateral view; (b) ventral view of body chamber. Note constriction preceding aperture and sudden egression of body chamber.

2. McM J1792, x 1; Yakoun Formation, Richardson Bay, Queen Charlotte Islands. Lateral view of phragmocone whorls showing fine, curved ribbing.

3a, b. McM J1792e, x 1; from 7-9 m above the base of the Yakoun Formation exposed at Richardson Bay, Queen Charlotte Islands. (a) ventral view of body chamber; (b) complete specimen with aperture, lateral view.

4. McM J1829, x 1; 1.5-2.5 m above the base of the Yakoun Formation exposed at Richardson Bay, Queen Charlotte Islands. Complete specimen with aperture, lateral view.

5. McM J1792b, x 1; from 7-9 m above the base of the Yakoun Formation exposed at Richardson Bay, Queen Charlotte Islands. Complete specimen with aperture, lateral view. Note sudden egression of body chamber and constriction.

6. McM J1792c, x 1; from 7-9 m above the base of the Yakoun Formation exposed at Richardson Bay, Queen Charlotte Islands. Complete specimen with aperture, lateral view. Note constriction preceding aperture, sudden egression of body chamber, curvature of both primary and secondary ribs.

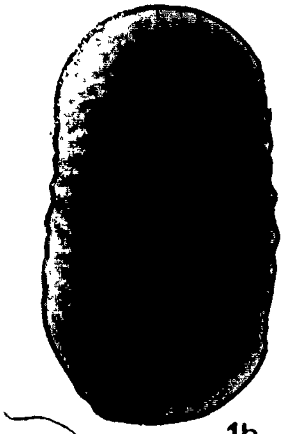
Figs. 7, 8. *Chondroceras defontii* (McLearn) ♂ [microconch]

7. Allotype, McM J1793a, x 1.5; from 18-21 m above the base of the Yakoun Formation exposed at Richardson Bay, Queen Charlotte Islands. Complete body chamber with aperture, lateral view.

8. GSC 48594, x 2; from Richardson Bay, Queen Charlotte Islands. Complete specimen with aperture, lateral view.

PLATE 13


1a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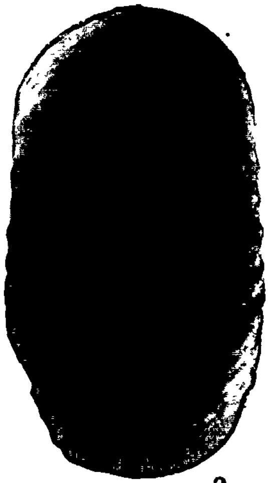
2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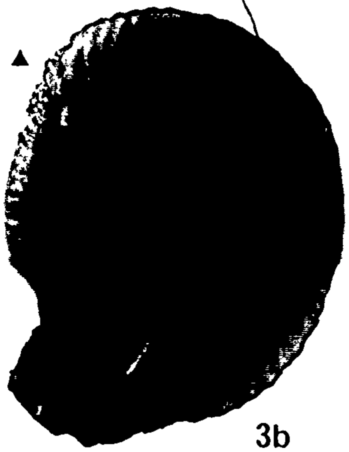
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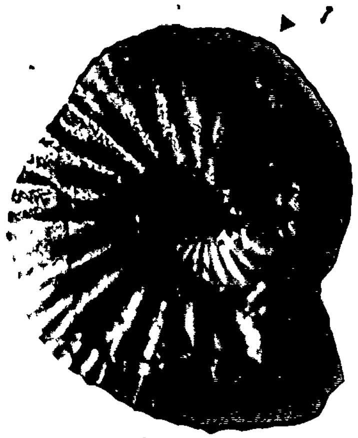
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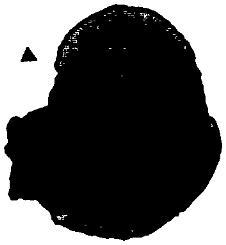
5


6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8

EXPLANATION OF PLATE 14

[All figures natural size unless otherwise indicated]

Figs. 1, 2. *Chondroceras allani* (McLearn) ♀ [macroconch]

1a, b. McM J1831d, both x 1; from the Rock Creek Member, Fernie Group, Ribbon Creek, southern Alberta. (a) lateral view of almost complete specimen showing curved primary ribs and egression of body chamber; (b) ventral view.

2a, b. McM J1830h, both x 1; from the Rock Creek Member, Fernie Group, Ribbon Creek, southern Alberta. (a) lateral view of almost complete specimen showing curved primary ribs and egression of body chamber; (b) ventral view.

Fig. 3. *Chondroceras* n. sp. indet. ♀ [macroconch]

3a-c. McM J1857a, all x 2; from just above the base of the exposed Yakoun Formation at MacKenzie Bay, Queen Charlotte Islands. (a) lateral view showing fine, curved primary and secondary ribbing; (b) lateral view showing strong curvature of ribs on inner whorls; (c) ventral view.

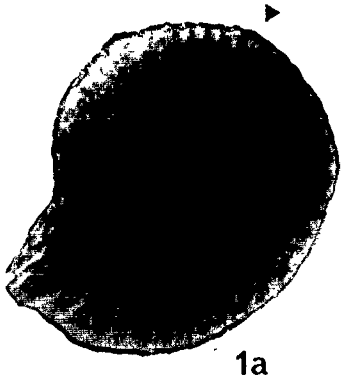
Fig. 4. *?Eutrephoceras* sp. indet.

4a, b. McM J1825a, x 1; from 38 m above the base of the exposed Yakoun Formation, South Balch Island, Queen Charlotte Islands. (a) lateral view, phragmocone; (b) ventral view.

Fig. 5. *Cenoceras* sp. indet.

5a, b. McM J1825b, x 1; from 38 m above the base of the Yakoun Formation exposed on the western shore of South Balch Island, Queen Charlotte Islands. (a) lateral view showing broad lateral lobe in suture; (b) dorsal view showing dorsal lobe of suture and position of siphuncle.

PLATE 14


1a

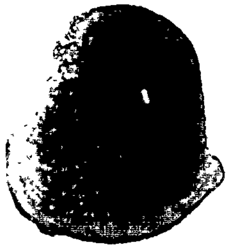

1b


2a


2b


4a


3b


3c


4b


5a


5b