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BULLETIN 155

**MIDDLE AND UPPER TRIASSIC SPIRIFERINID
BRACHIOPODS FROM THE
CANADIAN ARCTIC ARCHIPELAGO**

A. Logan

MIDDLE AND UPPER TRIASSIC
SPIRIFERINID BRACHIOPODS FROM THE
CANADIAN ARCTIC ARCHIPELAGO

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PREFACE

Brachiopods are widely distributed in the Triassic rocks of Canada but as yet few of these fossils have been studied in detail. This report, based on the study of relatively well preserved material, provides the first account of Triassic brachiopods from the Arctic.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, March 1, 1966

BULLETIN 155 — Spiriferide Brachiopoden der
mittleren und oberen Trias aus dem kanadischen
Arktischen Archipel.

Von A. Logan

БЮЛЛЕТЕНЬ 155 — Средне- и верхнетриасовые
спирифероподобные брахиоподы Канадского
Арктического архипелага.

А. Логан

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MIDDLE AND UPPER TRIASSIC SPIRIFERINID BRACHIOPODS FROM THE CANADIAN ARCTIC ARCHIPELAGO

Abstract

Late Middle Triassic (Ladinian) and early Upper Triassic (Karnian) spiriferinid brachiopods are recorded from the Schei Point and Blaa Mountain Formations of Ellesmere and Table Islands, Canadian Arctic Archipelago. Two new species of the genus *Spiriferina* are described: *Spiriferina (Spiriferina) ellesmerensis* of Ladinian age, and *Spiriferina (Rastelligera) canadensis* of Karnian age. Preservation of unaltered shell microstructures in *Spiriferina (Rastelligera) canadensis* permits detailed morphogenetic considerations of the internal structures of both valves to be made. *Spiriferina (Spiriferina) shalshalensis* Bittner, a Himalayan species of Karnian age, has been identified in Karnian rocks in the Canadian Arctic; *Spiriferina (Rastelligera) lundgreni* Boehm, originally described from the Upper Triassic of Spitsbergen, has been recognized in Ladinian-Karnian rocks in Canada. The validity of the subgenus *Rastelligera* Hector is confirmed and the taxon is reserved for those species of *Spiriferina* that possess a denticulate hinge margin.

Résumé

L'auteur signale des brachiopodes spiriférinidés du Trias moyen récent (Ladinien) et du Trias supérieur ancien (Carnien) dans les formations Schei Point et Blaa Mountain sur les Îles Ellesmere et Table, dans l'archipel Arctique canadien. Il décrit deux nouvelles espèces du genre *Spiriferina*: *Spiriferina (Spiriferina) ellesmerensis* d'âge ladinien, et *Spiriferina (Rastelligera) canadensis*, d'âge carnien. La conservation des microstructures non altérées de la coquille de la *Spiriferina (Rastelligera) canadensis* permet de faire des études morphogénétiques détaillées des structure internes des deux valves. La *Spiriferina (Spiriferina) shalshalensis* Bittner, une espèce de l'Himalaya d'âge carnien, a été trouvée dans les roches carniennes de l'Arctique canadien; la *Spiriferina (Rastelligera) lundgreni* Boehm, décrite originalement comme provenant du Trias supérieur au Spitzberg, a été identifiée dans les roches ladinienno-carniennes du Canada. La validité du sous-genre *Rastelligera* Hector est confirmée et l'on réserve ce nom aux espèces de *Spiriferina* possédant une charnière denticulée.

INTRODUCTION

Since the early 1950's the Geological Survey of Canada has evinced considerable interest in the thick sequence of Mesozoic and Tertiary rocks that forms the Sverdrup Basin in the Queen Elizabeth Islands, Canadian Arctic Archipelago. Previous history of geological exploration in the area has been recounted by Tozer (1960) and Fortier, *et al.* (1963); and early investigations of the Triassic formations and their fossils have been summarized by Tozer (1961). Only within the last decade, however, has our understanding of the precise nature of these rocks and their faunas been developed.

Deposits of Triassic age occur in the Sverdrup Basin, with exposures on Ellesmere, Axel Heiberg, Cornwall, Exmouth, Table, Cameron, Melville, Prince Patrick, Brock, and Borden Islands. Present knowledge of the Triassic faunas is due almost entirely to the work of Dr. E. T. Tozer. Tozer first visited the area in 1954 when he made preliminary observations on the Triassic faunas (Thorsteinson and Tozer, 1957; Fortier, *et al.*, 1963). Since then he has spent several summers in the Queen Elizabeth Islands and has added to the detailed stratigraphical and palaeontological knowledge of the Triassic rocks (1958, 1960, 1961, 1963, 1965a, b). A series of preliminary geological maps has also been published by the Survey.

As in northeastern British Columbia, ammonoids and bivalves have been used with some degree of success in the zonation of the Arctic Triassic and there has thus been almost no incentive for detailed collecting and systematic description of the isolated and often poorly preserved brachiopods, which prove, in the main, to be long ranging and sporadic in distribution, and therefore to have little stratigraphical value¹. However, it is not generally realized that the Triassic brachiopods of North America are a small and rather poorly understood group; indeed, G. A. Cooper remarks (*pers. com.*) that in the United States there is no good brachiopod-bearing representation of the Triassic. In Canada, isolated Triassic spiriferoids, terebratuloids, and rhynchonelloids have been recorded from British Columbia, Alberta, and the Yukon, but their true characteristics and affinities have rarely been investigated in detail. In 1964 the author re-described spiriferinids from the Middle and Upper Triassic of northeastern British Columbia

¹A summary of the value of Triassic brachiopods as zone fossils in British Columbia, Alberta, and the Yukon has recently been made by the writer (1964b).

and demonstrated that the Canadian examples were identical with forms from the Norian of Oman and the Himalayas (Logan, 1964a, b).

In 1963, a collection of brachiopods, made by Tozer in 1956 and 1957, Thorsteinsson in 1956 and 1957, and Round Valley Oil Company in 1961, was placed at my disposal by the Geological Survey of Canada.

Acknowledgments

Plastotypes, photographs, and specimens of comparative material were provided by Dr. H. Mutvei of the Riksmuseum, Stockholm; Dr. B. Kummel of Harvard University; Dr. N. F. Silberling of the U.S. Geological Survey, Menlo Park; and Drs. B. C. Roy and M. V. A. Sastry of the Geological Survey of India; Dr. Hermann Jaeger of the Humboldt University, Berlin, kindly provided examples of *Spiriferina* (*Spiriferina*) *rostrata* from his collection. The late Dr. C. T. Trechmann of Castle Eden, Durham, England, and Dr. C. A. Fleming of the New Zealand Geological Survey also contributed valuable information. Dr. G. A. Cooper of the U.S. National Museum critically read the manuscript and offered suggestions. The work was carried out during the tenure of a National Research Council post-doctorate fellowship with Dr. G. E. G. Westermann at McMaster University, Hamilton, Ontario, 1963-64.

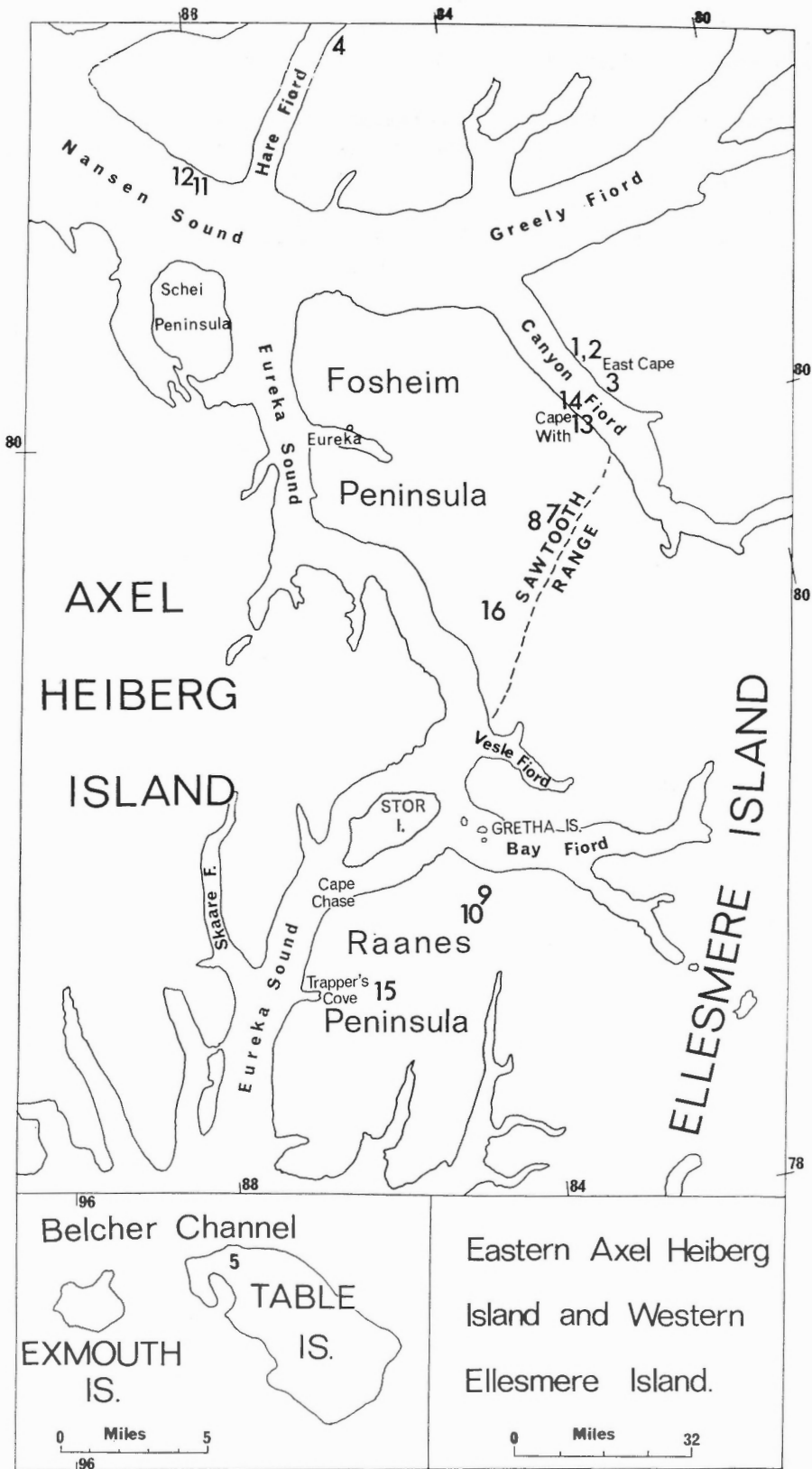
Stratigraphy

The specimens in question were collected principally from exposures on the western side of Ellesmere Island (Text-fig. 1) with three isolated examples from the north coast of Table Island (inset, Text-fig. 1).

With the exception of the Heiberg Formation, the Triassic rocks are of essentially marine facies and can be divided into:

(1) A shale-siltstone facies, characterized by grey-black shale, siltstone, and minor argillaceous limestone—these rocks are marine deposits typical of the axial part of the Sverdrup Basin. The lower Blind Fiord Formation is mainly siltstone; the overlying Blaa Mountain Formation is mainly shale.

(2) A calcareous siltstone-sandstone facies, with grey-brown calcareous quartz siltstone or fine-grained calcareous sandstone, with some interbedded limestones. These rocks are characteristic of the eastern, western, and southern margins of the Basin, where near-shore, rather coarse, clastic deposits were accumulating. The Bjerne Formation, which is only partly marine, is succeeded by the totally marine Schei Point Formation, the line of division being sharp. The relationship between the Blaa Mountain and Schei Point Formations has been discussed by Tozer (1960, p. 8; 1961, p. 23), who cites good faunal and lithological evidence for the contemporaneous nature of these deposits and for their Middle Triassic (Anisian-Karnian) age. Similarly, the Blind Fiord and Bjerne Formations are regarded as contemporaneous, although the evidence is not so complete as fossils



TEXT-FIG. 1. Eastern Axel Heiberg Island and western Ellesmere Island, showing Middle and Upper Triassic collecting localities (1-16, loc. 6 is NW of the limits of this Figure). Inset, Exmouth and Table Islands.

Triassic Spiriferinid Brachiopods from the Canadian Arctic

are rare in the latter formation. However, stratigraphical relationships with the Blind Fiord Formation, which contains fossils of definite Lower Triassic age, suggest a Lower Triassic age for the Bjorne Formation.

The overlying Heiberg Formation is mainly non-marine, and comprises a thick series of sandstones and shales which is relatively constant over both the axial and marginal parts of the Basin. Faunal evidence indicates an essentially Upper Triassic and Rhaetian age for this formation.

SYSTEMATIC PALAEOLOGY

Material and Techniques

Spiriferinid brachiopods are apparently restricted to certain calcareous siltstone and argillaceous limestone beds within the shaly sequence of the Blaa Mountain Formation, and to similar rocks in the Schei Point Formation (Anisian-Karnian). Most specimens were obtained for horizons of probable Karnian age. Their preservation is remarkably good, considering the nature of the sediments; some shells are partly or completely beekitized (this type of silicification is a common feature of Arctic fossils), although more typically there has been little replacement of the original calcareous shell. The specimens are usually found crowded together as a shell coquina (Pl. V, fig. 12) and many are in a complete and undamaged condition, even to the preservation of the very thin and delicate alate extremities. Both valves are normally found attached. Their state of preservation strongly suggests that they probably occur within a mile or two of their living positions.

The silicified specimens occur in a rather hard, buff-coloured calcareous siltstone and were separated in a bath of weak hydrochloric acid, when the calcareous cement was removed, leaving an insoluble, soft sandy residue that could be washed away from the silicified material. By this procedure, however, specimens only partly silicified tend to crumble when exposed to the atmosphere. All shells, although very thin and soft when first extracted from the acid bath, harden considerably on exposure to air.

Unsilicified specimens were much more difficult to prepare. A small vibrating tool was used successfully in the removal of hard matrix from the hinge areas, but the shells tended to split, exposing the median septum and dental plates.

Serial sections were made to elucidate internal structures; at each interval the specimen was polished, examined under the microscope, photomicrographs taken, and drawings made (x14), using a camera lucida attachment. Photographic reduction of these drawings then followed, the whole procedure being similar to that outlined by McLaren (1962) in the study of Devonian rhynchonelloids. Cellulose acetate peels were used for certain selected sections.

Measurements were made in millimetres of length of pedicle valve (Lp), length of brachial valve (Lb), maximum width (W), and maximum thickness (T) of those specimens selected as types. For slightly damaged specimens, reasonable estimates of the dimensions are given in parentheses. The incomplete nature of

most of the remaining specimens precluded accurate measurement; because of the relatively small number of complete specimens available for each species, growth and variation studies were not attempted. In the specific diagnoses specimens are referred to as "small" when they are less than 20 mm wide, "medium-sized" when 20 to 30 mm wide, and "large" when 30 mm or more.

Table I
Nomenclature¹ of Triassic Formations

Series	Stage	Axis of Sverdrup Basin	Margins of Sverdrup Basin
Jurassic		Overlying Jurassic rocks	
Rhaetian			
Upper Triassic	Norian	HEIBERG FORMATION Sandstones and shales, coals in upper part, two marine bands in lower part. Up to 4,700' thick	
	Norian or Karnian		
Middle Triassic	Karnian	BLAA MOUNTAIN FORMATION Grey-black shales and siltstones, with occasional calcareous siltstone and shale members. Up to 8,255' thick	SCHEI POINT FORMATION Grey calcareous siltstone and sandstone, with shales. Well-marked <i>Gryphaea</i> bed of calc-sandstone at top. Up to 1,500' thick
	Ladinian		
	Anisian		
Lower Triassic	Spathian	BLIND FIORD FORMATION Green and grey siltstone and shale. Up to 4,000' thick	BJORNE FORMATION Sandstone and conglomerate, much of formation non-marine. Less than 3,000' thick
	Smithian		
	Dienerian		
	Griesbachian		
Permian		Permian rocks	

¹Adopted by Tozer 1961, 1963

For each new species the author has attempted to choose as holotype a well-preserved specimen that is regarded as biologically typical of the species. The paratypes have been selected to show certain diagnostic characters not clearly emphasized on the holotype and to demonstrate the range of variation within the species. Incomplete and poorly preserved specimens have not been chosen as types, unless they illustrate important internal features. For information regarding collecting localities, horizons, and probable ages, the author has relied entirely on the Geological Survey of Canada (*see Locality Index*).

All types are in the collections of the Geological Survey of Canada, unless otherwise stated. The following abbreviations denote repositories: GSC, Geo-

logical Survey of Canada; USNM, United States National Museum; USGS, United States Geological Survey; RM, Riksmuseum, Stockholm; GSI, Geological Survey of India; NZGS, New Zealand Geological Survey.

Shell Structures and Terminology

Basically, the brachiopod terminology used in this report follows that defined by Muir-Wood (1934), Cooper (1944), and, more recently, Dunlop (1961). However, some terms have been used rather ambiguously by various authorities and require some clarification.

Shell Outline

The outline of the spiriferinid shell is denoted as either brachythyrid, megalthyrid, or megistothyrid. These terms have recently been re-defined and illustrated by the author (1964b).

Shell Microstructure

The spiriferinid group is characterized by an endopunctate shell, the punctae penetrating all layers of the shell. There are normally three shell layers present: an outer external layer of "fibrotest" which is only intermittently preserved; a thick "prismotest" showing dark oblique calcite crystals and growth lines; and an opaque internal "callotest" of vertical calcite prisms which also show growth lines. This terminology follows that used by Vandercammen, and Ager and Riggs—the table below indicates the equivalent shell layers of Miloradovitsch, Williams, and Dunlop.

Miloradovitsch (1937)	Williams (1956)	Dunlop (1961)	Vandercammen (1959) Ager and Riggs (1964)
Periostracum	Periostracum	—	—
Lamellated layer	Primary layer	Lamellar layer	Fibrotest
Fibrous layer	Secondary layer	Fibrous layer	Prismotest
—	Prismatic layer	Columnar layer	Callotest

Many specimens of *Spiriferina (Rastelligera) canadensis* n. sp. from the Canadian Arctic had suffered little or no recrystallization during diagenesis and therefore were useful in elucidating the shell microstructures and growth histories of the various internal organs. The following observations on the morphogenesis of pedicle and brachial valve structures are based solely on transverse sections of this species, unless otherwise stated.

Pedicle Valve Structures

Median Septum

This structure, defined by Dunlop (1961, p. 491) as "any plate in the longitudinal median plane of either valve" is highly distinctive in *Spiriferina*, especially in the pedicle valve. Some of the various profiles of the septum are illustrated in Text-figure 4.

The function of the ventral median septum in brachiopods is threefold:

(1) To act as a muscle platform for the support of a spondylium, where one is developed, i.e., cyrtinids;

(2) To act, in its own right, as a muscle attachment and to strengthen the valve at a place of great muscular strain;

(3) To serve as a breakwater for inhalent lateral water currents and enable the lophophore to extract food particles.

In the productoid brachiopods, for example, the median septum is typically developed in the brachial valve and serves to divide the adductor muscle scars, which are themselves raised up on platforms. Muir-Wood and Cooper (1960) cite no evidence for direct attachment of muscles to the median septum and its main purpose here appears to be as in (3). In rare instances, a true ventral median septum is developed in this group (e.g., *Septarinia*, *Tschernyschewia*) but more commonly this septum takes the form of a low ridge. *Tschernyschewia* has a ventral median septum very like that of *Spiriferina* and Muir-Wood and Cooper (p. 127) suggest that it is "possibly the seat of muscle attachments."

In *Spiriferina* the occurrence of grooved muscle scars on the flanks of the ventral median septum has been recorded by Hall and Clarke (1894, p. 53, fig. 42) in *Spiriferina* (*Spiriferina*) *walcotti* (Sowerby). These grooves are not to be confused with the fine and regular growth lines often seen in specimens of this genus and illustrated in Text-figure 4a-f, Plate I, figure 5 and Plate III, figure 4. Thus, although it is probable that the sharp ventral median septum in *Spiriferina* was used as a muscle attachment, direct evidence of grooves is lacking in most species, and it is possible that the septum performed a dual function, acting also as a breakwater to inhalent currents entering the shell laterally and antero-laterally.

The development of the ventral median septum in *Spiriferina* was first demonstrated by Oehlert (1901, fig. 3) who illustrated four transverse serial sections through the beak of *Spiriferina* (*Spiriferina*) *rostrata* (Schl.) from the Upper Lias of Albarracin, Spain. His figures show the median septum originating from the floor and meeting the inner edge of the delthyrial plate. The sharp line of junction between the two plates is erased, doubtless due to recrystallization of the callotest shell material. It was upon these figures of Oehlert that Fredericks (1919) based his controversial remarks concerning the origin of the median septum. This septum in the Mesozoic spiriferinids is, according to Fredericks, not a true septum (or "euseptum") as in the Palaeozoic representatives (the term "euseptum" was defined as a "median ridge formed by the duplication of the inner layers of the shell"), but a "pseudoseptum" (defined as "a strongly developed

syrinx plate, built by enlargement and parallel extension of this syrx plate"). The structure of *Spiriferina* was later more fully described by Fredericks (1927) as consisting of dental lamellae, a delthyrial plate and a "pseudoseptum". The delthyrial plate was supposed to cover the upper end of the delthyrium and to be inserted between the bases of the apical (dental) plates. A transverse section through *Spiriferina* (*S.*) *rostrata* (Schl.) was figured by Fredericks (Pl. 1, fig. 16) in an attempt to show its separation from *Spiriferellina* Fred., an upper Palaeozoic genus. Fredericks was of the opinion that the "pseudoseptum" is homologous with the syrx of *Syringothyris* Winchell, and is supposedly derived from the inner edge of the delthyrial plate, developing the features of a median septum by continuous growth onto the floor of the valve and forward growth towards the anterior margin. Thus, Fredericks was suggesting that the Mesozoic representatives of *Spiriferina* are the end-forms of the *Syringothyris* stock, a view that Paeckelmann (1931) conservatively adopted, although expressing some misgivings on the interpretation of the origin of the "pseudoseptum". He suggested that further investigation of the nature of the spiralia and juga in these forms should be made before any phylogenetic conclusions were drawn.

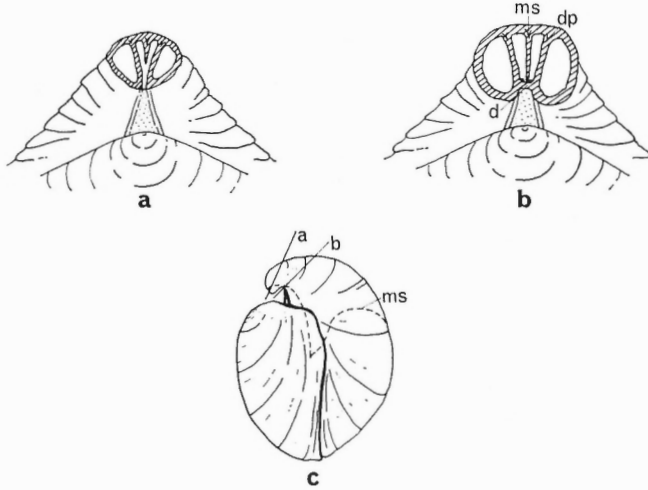
North (1920) was totally opposed to a suggestion made earlier by Vaughan (1905) that *Spiriferina* and *Syringothyris* were related. He believed the median septum to be completely unrelated to the syrx-bearing transverse plate of *Syringothyris*, stating that "the two structures, a median septum and a syrx-bearing transverse plate, could not coexist in the same shell, since they would mutually interfere with one another." Furthermore, he believed that the syrx and transverse plate of *Syringothyris* originated as a modification of an apical callosity in Middle Devonian forms, whereas the median septum of both the upper Palaeozoic and Mesozoic spiriferinids was a feature already independently developed in "early Palaeozoic spiriferoids".

Kirchner (1934) attempted to apply the conclusions of Fredericks to his study of *Spiriferina* (*Spiriferina*) *fragilis* (Schl.) from the Upper Muschelkalk of Wurzburg, Germany. In this species he found two divergent plates ("delthyrial apophyses") on the inner surface of the delthyrial plate, which became more massive anteriorly, finally merging with a rather weak "euseptum" to form a "zusammengesetztes septum" (compound septum). This peculiar structure was regarded by the author as a possible transition stage between the true euseptoid condition of the Palaeozoic forms and the pseudoseptoid condition advanced by Fredericks for the Mesozoic *Spiriferinas*. I have not been able to verify Kirchner's observations on *S. (S.) fragilis*, but it is certain that most of the Triassic representatives of *Spiriferina* show a euseptoid condition.

Miloradovitsch (1937) was openly critical of Fredericks' observations. He drew attention to the fact that Oehlert himself believed that the median septum in *S. rostrata* was formed from the floor of the delthyrial cavity, and that Fredericks was probably "led astray by the figure, without getting acquainted with the text."

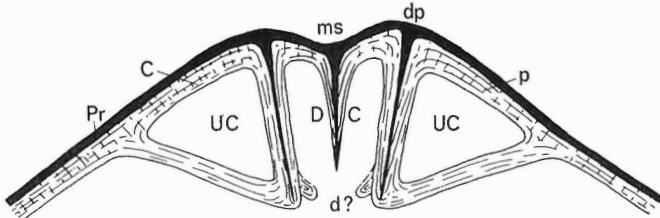
As I interpret Fredericks' terms, a "euseptum" is a duplication of the inner layers of the shell floor, with growth proceeding in an upward direction from the

Triassic *Spirifer* Brachiopods from the Canadian Arctic



TEXT-FIG. 2a-c. *Spiriferina* (*S.*) *rostrata* (Schl.). a and b, camera lucida drawings of serial transverse sections of beak of pedicle valve, at 0.05 mm and 0.3 mm respectively from the apex of the umbo, $\times 8$. c, side view of shell, showing position of sections a and b, $\times 1\frac{1}{2}$. ms = median septum, dp = dental plates, d = delthyrial plate. GSC No. 20419, Lias, Balingen, Württemberg, Germany.

floor and thereafter in a forward direction, whereas a “pseudoseptum” is formed from the inner edge of the delthyrial covering plate, with initial growth in a downward direction (i.e., towards the valve floor) and, after merging with the shell layers of the floor, subsequent growth of the septum in an anterior or forward direction. Examination of the beak region in specimens of *S. (S.) rostrata* from the Lias of Balingen, Württemberg, Germany (Text-fig. 2a-c) and *S. (S.) walcotti* from the Lias of Radstock, England, shows that, at the extreme apex of the pedicle valve (Text-fig. 2a), the median septum is an integral part of the floor of the valve and is independent of the delthyrial covering. A section at 0.3 mm from the apex (Text-fig. 2b) shows the septum in confluence with the inner edge of the covering, but not originating from it, as Fredericks suggested. A reconstruction of the shell in relation to these two sections is shown in Text-figure 2c. Further evidence is provided by growth lamellae in the shell substance of *Spiriferina* (*Rastelligera*) *canadensis* n. sp. from the Canadian Arctic Triassic (Text-fig. 3). Here it can be seen that the prismotest of the floor of the valve is continuous with the central rod of the median septum and dental plates, with callotest material accumulating concentrically in the delthyrial and umbonal cavities. These observations are in accordance with those of Dunlop (1961, p. 497) who notes that, in *Spirifer trigonalis* (Martin), the delthyrial plate, although formed internally by a mantle fold in the delthyrial cavity, is independent of the septum, which is secreted by a separate fold of the mantle on the floor of the valve.

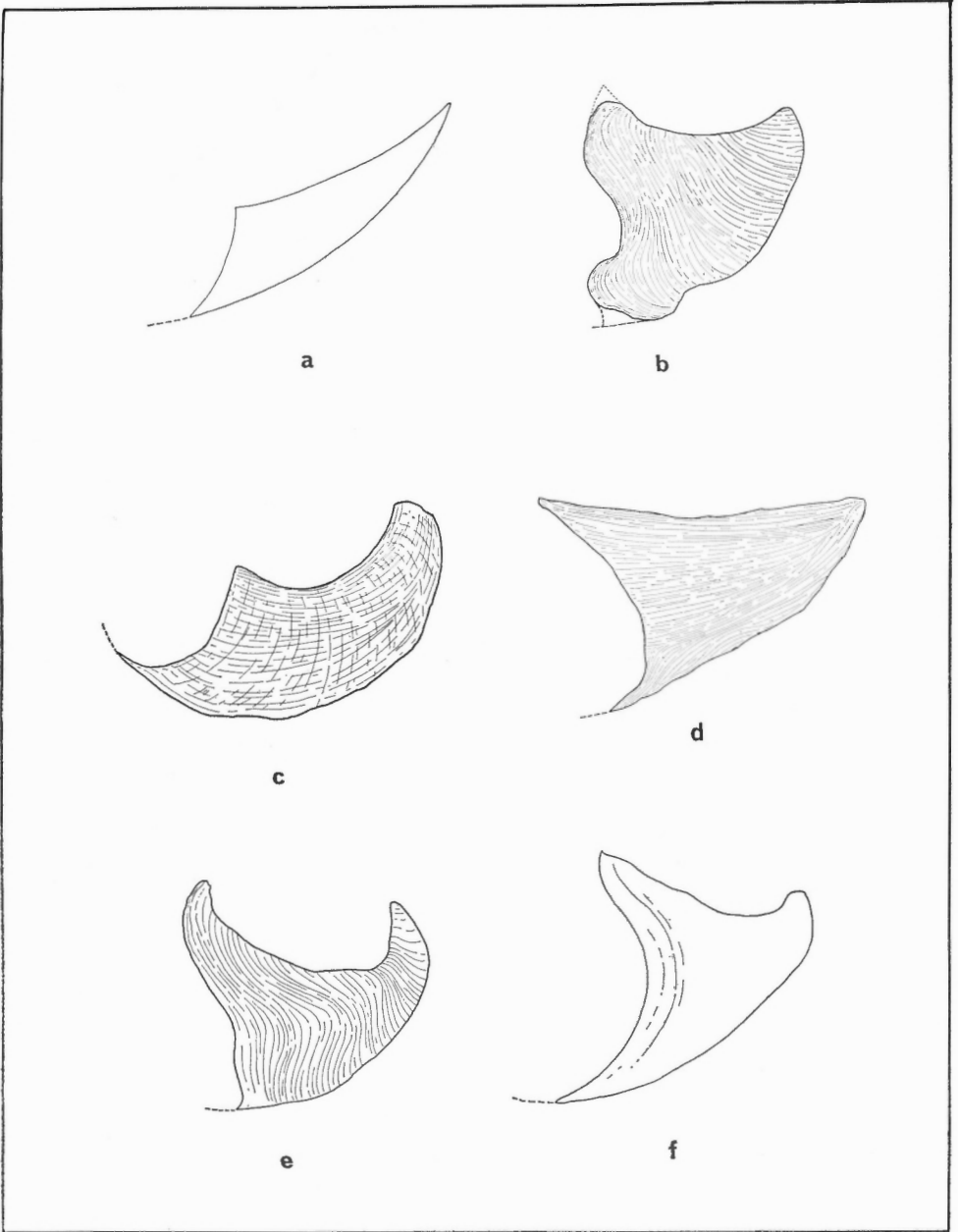


TEXT-FIG. 3. *Spiriferina (Rastelligera) canadensis* n. sp. Camera lucida drawings of a transverse section of pedicle valve, at 3.0 mm from apex of umbo, x3, GSC No. 20407. ms = median septum, dp = dental plates, d = delthyrial plate, p = punctae, Pr = prismatic, C = callotest, UC = umbonal cavity, DC = delthyrial cavity.

Thus we may assume that, as progressive reduction of the mantle lobes responsible for the septum continued, due to growth of callotest within the cavities, the septum was built up by successive layers of callotest produced mainly by growth in an upward and forward direction. Median longitudinal sections of median septa in species of Triassic and Liassic *Spiriferina* from British Columbia, Arctic Canada, and Europe have been illustrated (Text-fig. 4a-f). Most show well-defined growth lamellae, which may mark successive positions or pauses in the growth of the callotest. These growth lines indicate both straightforward upward growth from the valve floor (Text-fig. 4c, d) and upward and forward growth from the apex towards the anterior margin (Text-fig. 4b, c). Although growth may possibly be the product of vertical extension of the delthyrial covering, as for example in *Spiriferina (Spiriferina) fragilis* Schl., most of the Triassic species show septal structures that are unrelated to the covering of the delthyrium, and the median septum of *Spiriferina* is in no way derived from the syrxin-bearing transverse plate of *Syringothyris* Winchell.

Dental Plates

Dunlop (1961) has recently re-defined the dental (or apical) plates as "two vertical plates which project from the delthyrial margins, across the apical cavity to the floor of the valve." The dental plates and median septum thus divide the cavity into a central delthyrial cavity (DC, Text-fig. 3) and two lateral umbonal cavities (UC, Text-fig. 3). Anteriorly, the dental plates terminate at the hinge margin of the valve in a pair of rather bulbous teeth, which fit into corresponding sockets in the opposite valve. The dental plates are composed essentially of callotest ("columnar" layer of Dunlop). Miloradovitsch (1937), from a study of shell growth in *Squamularia lineata*, concluded that the dental plates are in complete continuity with the valve walls and attributed their origin to long folds of the mantle covering the bottom of the valve and the dental plates. Ager and Riggs (1964) confirmed these observations in the Upper Devonian *Spinocyrtia iowensis*. Dunlop (1961) was in complete agreement with these authors regarding the mode of formation of the dental plates, stating that in *Spirifer trigonalis* "the dental plates were formed



TEXT-FIG. 4a-f. Camera lucida drawings of longitudinal profiles of median septa in various species of *Spiriferina*, $\times 5$. a, *S. (Rastelligera) lundgreni* Boehm (GSC No. 20413); b, *S. (R.) canadensis* n. sp. (GSC No. 20397); c, *S. (S.) ellesmerensis* n. sp. (GSC No. 20377); d, *S. (S.) shalshalensis* Bittner (GSC No. 20391); e, *S. (S.) abichi* Oppel, Pardonet Formation, British Columbia; f, *S. (S.) rostrata* (Schl.), Lias, Europe.

within two parallel, longitudinal invaginations of the mantle which extended from the delthyrium across the apical cavity to the floor of the valve, each side of a plate being formed by secretion from one side of a fold." She recognized also the distinctive central line that divides the dental plate into two equal parts, but found that the formation of the plates occurred some time after the thickening of the outer layers of the shell, for the bases of the plates were not continuous with the outer shell walls.

In *Spiriferina (Rastelligera) canadensis* n. sp. it can be seen that the dental plates are not parallel, but converge to meet the central median septum at the apex of the umbo (Text-fig. 8). All three plates appear to have been formed at the same time, their composition being initially of prismotest in continuity with the outer shell layer of the valve floor; this central rod of dark calcite presumably acted as a support for the later concentric deposition and infilling of the cavities by white callotest material, which accompanied the progressive reduction in the size of the mantle lobes. Similar extensions of the prismotest were observed by Vandercammen (1959, p. 21) in the dental plates of the Devonian *Cyrtospirifer*. At the earliest stage, then, there are no definite delthyrial or umbonal cavities, for they are completely infilled with callotest material. Later, it can be clearly seen from the concentric growth lines that the callotest of the dental plates and septum is continuous with that of the shell floor. Thus it may be concluded that the mantle in the apical region of the pedicle valve in *Spiriferina* was invaginated into three longitudinal lobes responsible for the contemporaneous deposition of the dental plates and median septum.

Dental Ridges and Flanges

There is no evidence in the species of *Spiriferina* examined for the existence of dental ridges and flanges of the type described by Dunlop (1961) in *Spirifer trigonalis* (Martin).

Delthyrial Covering

In brachiopods, the triangular delthyrium may be sealed, partly or completely, by either:

(1) A single flat or convex plate (pseudodeltidium), growing from the apex in an anterior direction; or

(2) A pair of triangular, discrete deltidial plates, growing laterally and anteriorly from the edges of the delthyrium. In either, the covering is considered to be an internal structure overlain by the mantle throughout life (Williams, 1956; Dunlop, 1961).

In *Spiriferina*, the delthyrium is usually open, but the former presence of a covering may sometimes be inferred from the grooves that flank the delthyrium. There is evidence for both types of covering in *Spiriferina*. Davidson (1851-52, p. 22) remarked in his descriptions of *Spiriferina (S.) rostrata* (Schl.) that the covering is remarkably well preserved in specimens from the Lias of Vieux Pont, Normandy, "being formed of two pieces united in the form of a roof" (discrete

deltidial plates). However, a specimen of *Spiriferina* (*Rastelligera*) *lundgreni* Boehm from the Schei Point Formation of Canyon Fiord, Ellesmere Island (GSC loc. 28430) showed the presence of a short, flat pseudodeltidium, extending about one third of the distance from the apex towards the anterior end of the delthyrium (Pl. 5, fig. 8). Similarly, a sectioned specimen of *Spiriferina* (*Rastelligera*) *canadensis* n. sp. (Text-fig. 3) from Emma Fiord, Ellesmere Island (GSC loc. 32370) shows traces of the anterior end of a delthyrial plate (or plates), which may be analogous to the delthyrial plate structures described by Ager and Riggs (1964) in *Spinocyrtia iowensis* (Owen) and said by them to be the result of shell secretion from two folds of the mantle lobe directed inwardly from the sides of the delthyrial cavity.

There appears to be no evidence in the specimens examined of any apical perforation and it must be assumed that the pedicle stalk is atrophied in *Spiriferina*, unless it emerged from the concave anterior extremity of the delthyrial covering.

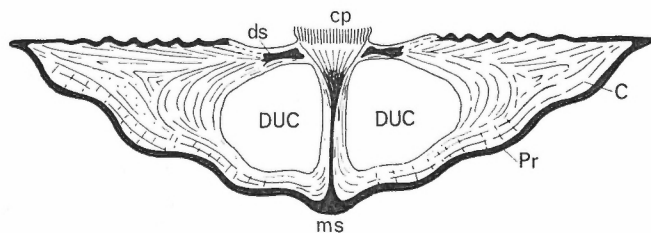
Delthyrial Angle

The delthyrial angle is the acute angle of divergence between the two postero-lateral margins of the delthyrium, usually identical in *Spiriferina* to the angle of divergence of the dental plates, which bound the delthyrium.

Brachial Valve Structures

Cardinal Process and Supporting Structures

In the early stages of development of the brachial valve, the umbonal region is filled with callotest material, with the beginnings of a rather tenuous dorsal median septum just discernible. Further sectioning reveals that the purpose of this septum is solely one of support for the heavy, striated, comb-like cardinal process, which has a wide anterior part, narrowing at its base towards the median septum. Flanking the dorsal median septum, which, like its counterpart in the opposite valve, is seen to have a central rod of prismotest, are two cavities, here designated the dorsal umbonal cavities (DUC, Text-fig. 5).



TEXT-FIG. 5. *Spiriferina* (*Rastelligera*) *canadensis* n. sp. Camera lucida drawings of transverse section of brachial valve, at 1.2 mm from apex of umbo, x3. GSC No. 20407. cp = cardinal process, ds = dental sockets, ms = median septum, Pr = prismotest, C = callotest, DUC = dorsal umbonal cavity.

The cardinal process is striate and in cross-section is seen to consist of eleven or more thin, parallel lamellae. Anteriorly the cardinal process merges with the socket plates, completely surrounding them with shell material (Text-fig. 5). It seems likely that both the cardinal process and the supporting median septum were deposited by a fold in the dorsal mantle lobe analogous to that which deposited the median septum and dental plates in the valve (Dunlop, 1961).

Hinge Plate and Dental Sockets

Details of hinge plate structures were not well shown in the sections of *Spiriferina (Rastelligera) canadensis* n. sp., but could be seen in unsectioned specimens of *Spiriferina (Rastelligera) lundgreni* Boehm. Here the hinge plate appears to be a divided one, consisting primarily of two outer plates, which are raised up on either side of the dental sockets to form socket ridges ("s" and "f" of Text-fig. 9). An inner hinge plate, uniting the crural bases, is not present.

The growth lamellae within the dental sockets in *Spiriferina (Rastelligera) canadensis* suggest asymmetrical growth of the type described by Ager and Riggs (1964, fig. 4), with the development of inner socket ridges as supporting structures. There is little evidence of outer socket ridges in this species.

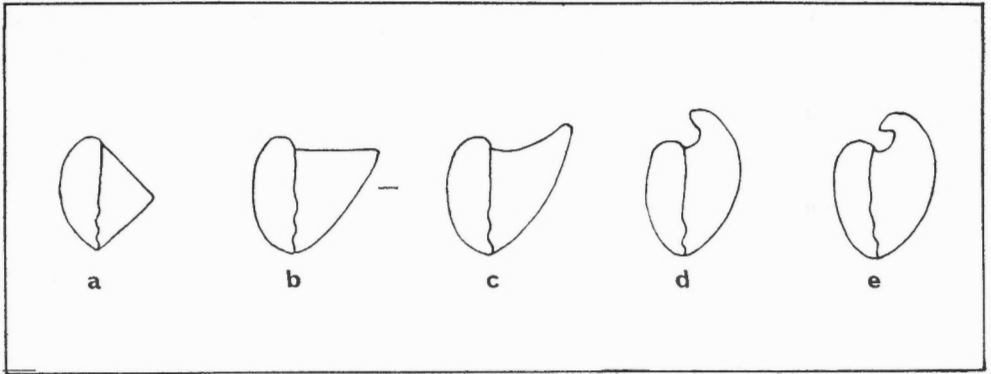
Crura and Crural Plates

The two inwardly directed crura descend from the crural bases beneath the socket plates, but little can be said concerning the exact nature of the crural plates or whether they extend the length of the dental sockets. At about half the length of the valve, the crura begin to rotate about a central axis parallel to the shell width and form the spiralia. The microstructure of the spiranium was not retained in any of the specimens of *Spiriferina* examined.

Valve Interareas

The terminology of the curvature of the pedicle valve interarea (Text-fig. 6) follows that of Vandercammen (1959); it is useful in delimiting species, although it must be remembered that the curvature may change during ontogeny and thus only adult forms should be compared (Moore, *et al.*, 1952). The interarea itself, which may be defined as the plane outer surface of the palintrope, or the flat shelf beneath the beak ("i" of Text-fig. 9) of either valve, may be smooth, longitudinally striated parallel to the hinge line and/or transversely striated normal to the hinge line. Those forms which show transverse striae may be conveniently subdivided into:

(1) Those in which the transverse ridges on the pedicle valve interarea are directly opposed to similar ridges on the interarea of the opposite valve (e.g., *Syringospira* Kindle, *Sphenospira* Cooper). The ridges are confined to the outer shell layer and do not affect the outline of the hinge margin. They are believed in certain forms to have been used in conjunction with a wide flange (a lateral extension of the palintrope), as a means of attachment for a specimen lying on its interarea (Cooper, 1954).



TEXT-FIG. 6a-e. Terminology of curvature of pedicle valve interarea, after Vandercammen, 1959. a = anacline, b = orthocline, c = apsacline, d = catacline, e = procline.

(2) Those in which the transverse ridges on the interarea are a reflection of the structure of the inner layers of the shell, resulting in crenulations at the hinge margin. In this form, the ridges are separate (occasionally bifurcating, as in *Spirifer*, *Alispirifer*, and *Acanthospirifer*) and interlock with those of the opposite valve. These so-called "hinge teeth" are relatively common in the spiriferoids, and have been described in Devonian forms, such as *Cyrtospirifer* Nalivkin by Vandercammen (1959); Carboniferous forms such as *Spirifer trigonalis* (Martin) by Davidson (1861), Young (1884), and Dunlop (1961); *Spirifer forbesi* Norwood and Pratten, *S. increbescens* Hall, and *S. lateralis* Hall, by Hall and Clarke (1894); species of *Syringothyris* Winchell and *Punctospirifer* North, by North (1920), and *Alispirifer* Campbell by Campbell (1961). Denticulate hinge margins in Permian forms were noticed by King (1850) in *Pterospirifer alatus* (Schl.); other Permian denticulate forms include *Spiriferinaella* Fredericks. Triassic genera include *Spondylospira* Cooper, *Zugmayerella* Dagens, and *Spiriferina* D'Orbigny. For those species of *Spiriferina* with denticulate hinge margins, the subgeneric name *Rastelligera* Hector has been used (see later discussion).

Young (1884, p. 18) commented upon the nature of the hinge area in *Spirifer trigonalis*, noting the resemblance of the denticles to the taxodont arrangement of the teeth in the modern bivalve *Arca*. He was able to count thirty-five separate denticles on each side of the delthyrium, and suggested that they might be caused by parallel bands of recrystallized aragonite. Hall and Clarke (1894, Pl. 31, fig. 3) clearly illustrated the denticulate cardinal edge of the pedicle valve in *Spirifer increbescens* Hall and showed that the brachial valve margin was equipped with a series of small sockets for the reception of the denticles of the opposite valve. North (1920, p. 172) described similar structures on the interarea of *Syringothyris* Winchell, but was unable to confirm Young's observations in his specimens. Vandercammen (1959, pp. 30-34) noted that in specimens of *Cyrtospirifer* the area of transverse striation was limited (as in *Syringothyris*) to a relatively small, central, triangular area bordering the delthyrium. He was uncertain, however, as to

whether the feature was caused by secretion from an external wad of tissue covering the cardinal interarea (= periostracal pad of Williams, 1956) or by an internal accumulation from the edge of the mantle.

The valuable research of Williams (1956) on the interareas of Recent brachiopods may suggest their mode of formation in the fossil forms. Following this author, we may postulate that, in the spiriferoids, the inner edges of the interareas abut (and sometimes interlock) against one another, the fusion of the outer mantle lobes forming a "generative zone" anterior to the hinge line. The outer epithelium of the fused mantle lobes in this region is presumably responsible for the formation of both longitudinal ("growth ruts") and transverse striae. Externally, a thick chitinous pad of periostracum, which is continuous with the thin periostracal covering of the rest of the shell, is wedged into the more or less curved interareas of both valves, filling the longitudinal and transverse grooves and acting as a supplementary aid to the normal articulating media. This pad is spun out, according to Williams, at the hinge line and is continuous with the periostracum secreted by the closed end of the deep mantle groove separating the outer and inner epithelial lobes at the mantle edge. Thus the interarea has a complex growth history; although it is certain that the denticle tracks are the product of the fused mantle lobes, it is not impossible that, in some forms, the periostracal pad was at least partly responsible for the deepening of the tracks.

Dunlop (1961) remarked upon the denticle tracks in *S. trigonalis*, noting that the brachial valve possessed grooves only. This appears to be so in *Spiriferina (Rastelligera) lundgreni* Boehm (Pl. V, fig. 4) and *Spiriferina (Rastelligera) canadensis* n. sp. (Pl. IV, fig. 5). Dunlop further states that the striations occur only in the fibrous layer (=prismotest) and if the lamellar layer (=fibrotest) is present, the striations are completely obscured. Trechmann (1917) made a similar observation with regard to *Spiriferina (Rastelligera) diomedea* Trech. from the New Zealand Triassic. Thus only specimens that have been weathered, however slightly, will show denticles. If this is correct, then only the longitudinal striae would have been filled by the periostracal pad, and the transverse striae would have been formed internally by the mantle.

Hinge Margin

The hinge margin ("m" of Text-fig. 9) is defined as the anterior edge of the palintrope in both valves.

Classification of *Spiriferina* D'Orbigny

The history of the classification of the genus and its separation from related Palaeozoic and Mesozoic genera has already been described by the author (1964b, pp. 695-703). To the list of Triassic forms mentioned at that time should be added the genera *Pseudocyrtina* Dagys, *Sinucosta* Dagys, and *Guseriplia* Dagys from the Caucasus region, U.S.S.R. *Pseudocyrtina* Dagys, with type species *P. norica* Dagys, is a form distinguished externally by its unusually high pedicle valve

interarea. The internal structure is similar to that of *Spiriferina*. *Sinuocosta* Dagys, with type species *S. emmrichi* (Suess), is a very finely ribbed genus, the costae extending into the sulcus fold region; *Guseriplia* Dagys, with type species *G. multicosata* Dagys, is a more coarsely ribbed spiriferinid with two to three ribs in the sulcus fold region. Both these genera resemble *Spiriferina* in their internal structure; thus Dagys's three genera may ultimately prove to have, at the most, only subgeneric status.

Description of Species

Class ARTICULATA

Order SPIRIFERIDA Moore, 1952

Superfamily SPIRIFERINACEA Davidson, 1884

Family SPIRIFERINIDAE Davidson, 1884

Subfamily SPIRIFERININAE Davidson, 1884

Genus *Spiriferina* D'Orbigny, 1847

Subgenus *Spiriferina*

Type species. Terebratulites rostratus Schlotheim, 1822, p. 260, Pl. 16, fig. 4a-c.

The holotype is preserved in the Palaeontological Institute and Museum of Humboldt University, East Berlin (Cat. No. Qu. Kat. 2. 15. 1., p. 828) and has recently been re-illustrated (Logan, 1964b, pl. 2, fig. 3a-f). The problem of the type locality was also discussed at that time (p. 703).

Diagnosis. Shell small to large, with considerable variation in outline, from forms without cardinal extremities, in which the hinge line is less than the greatest width of the shell (brachythyrid), through forms slightly broader than long, without cardinal extremities (megathyrid), to alate forms, with produced cardinal extremities (megistothyrid). Cardinal interarea of pedicle valve triangular and usually rather low, longitudinally striate; cardinal ridges sharp to rounded. Delthyrium open, or closed by either a pseudodeltidium or discrete deltidial plates; brachial valve with low, almost imperceptible interarea and notothyrium. Pedicle valve with prominent smooth or costate median sulcus, producing a corresponding fold in the brachial valve. Variation in type of costation and number of costae, from forms almost completely smooth to forms costate on lateral flanks and sinus fold region. Surface ornamentation also variable, some forms densely spinous, others smooth. Shell substance endopunctate, concentric growth lamellae on external surface.

Pedicle valve with a strong euseptoid median septum which joins the dental plates where these are in contact at the umbo. Hinge teeth normally strong, with the delthyrial margin supported by strong divergent dental plates, which are almost parallel to the septum, and attached to the valve floor between the first and second costae. The median septum and dental plates have concave anterior margins, but the septum extends farther anteriorly, usually terminating in a recurved blade-like projection.

Brachial valve with short laminated cardinal process, occasionally supported by a weak median septum. Strong dental sockets on each side of the cardinal process, often flanked by socket ridges or buttresses, formed from the outer plate of

a divided hinge plate. The two crura issue from beneath the sockets and are united at about the mid-line by a simple, curved, transverse jugum. Spiralia of twelve to fourteen volutions in each outwardly directed spire; often spiralia are pectinated on the anterior face.

Spiriferina (Spiriferina) ellesmerensis n. sp.

Plate I, figures 1-7; Text-figs. 4c, 7A

Diagnosis. Shell small, equally biconvex; hinge line straight or slightly curved, outline brachythyrid approaching megathyrid; width slightly greater than length. Cardinal interarea of pedicle valve small, triangular; curvature catacline to procline, with highly incurved beak. Interarea with no trace of longitudinal striae. Delthyrium triangular and open, but possibly may have been covered by either pseudodeltidium or discrete deltidial plates, no longer preserved but suggested by traces of very thin marginal grooves (Pl. I, fig. 4a). Delthyrial angle 57 to 60 degrees.

Pedicle valve with wide, smooth, U-shaped median sulcus; lateral costae rounded to subangular, deep, usually three or four on each flank of both valves, including those which demarcate the sulcus; costae complete and extending from anterior margin to umbo. Umbo of brachial valve small and incurved over a narrow interarea, notothyrium not seen. A broad, smooth fold, flattened at the crest, corresponds to median sulcus in pedicle valve. Shell substance endopunctate.

Pedicle valve interior with strong median septum extending two thirds length of valve, concave anteriorly, terminating sharply in a recurved projection. Dental plates strong, divergent, joining septum at umbo, and supporting strong teeth that fit into sockets in the opposite valve. Internally, brachial valve with laminated cardinal process, apparently unsupported by even a weak median septum. Spiralia with twelve volutions in each spire; jugum not seen.

Types and Dimensions.

Specimen		Locality	Lp	Lb	W	T
Holotype	20373	28759	14.5	11.2	17.1	9.5
Paratype 1	20374	28431	14.0	11.2	15.7	9.5
Paratype 2	20375	28431	—	—	(15.0)	—
Paratype 3	20376	28431	—	—	11.0	—
Paratype 4	20377	28431	—	—	—	—
Paratype 5	20378	28759	15.9	(12.2)	15.5	10.0
Paratype 6	20379	28759	9.3	7.7	11.4	6.1

Remarks. A single specimen of a variety of this species from the Schei Point Formation, *Nathorstites* bed (Ladinian), north coast of Table Island (GSC loc. 30353) shows more angular lateral extremities and cardinal ridges, and up to five

lateral costae on the flanks. In addition, there is a trace of a very thin ridge or median septum in the brachial valve which is not seen in regular examples of *Spiriferina* (*S.*) *ellesmerensis*.

Comparisons. *Spiriferina* (*S.*) *ellesmerensis* appears to be very closely related to *Spiriferina* (*S.*) *mansfieldi* Girty (in Girty and Mansfield, 1927, p. 436, pl. 30, figs. 17-19) from the Lower Triassic (Scythian) Ross Fork Limestone of the Thaynes Group, Idaho. This species, however, has sharp angular cardinal ridges in the small valve, which demarcate the large interarea from the beak region. In addition, the pedicle valve is much more conical than in the Canadian form, with the shoulders sloping rather abruptly. There are three to four very angular ribs on the flanks, although the shell surface is covered with a series of fine spines or pustules, according to Girty. Six of Girty's topotypes (USGS loc. 7879) were kindly loaned by Dr. Silberling of the USGS—two of the better-preserved individuals are figured (Pl. I, figs. 8, 9) for comparison (now USNM 147421, 147422). A photograph of the holotype of *Spiriferina* (*S.*) *homfrayi* (Gabb) (Cat. No. 30798, Acad. Nat. Sciences of Philadelphia) from the Anisian (?) of Star Canyon, Humboldt Range, Nevada, suggests possible identity with *S.* (*S.*) *mansfieldi*; however, an examination of the plastotypes of *S.* (*S.*) *homfrayi*, as described by Smith (1914, p. 147, pl. 94, figs. 12-14) from the Middle Triassic of New Pass, Nevada (USNM No. 74440) shows that Smith's specimens are not conspecific with the holotype and appear to represent a different species.

Spiriferina (*S.*) *orophila* Diener (1908, p. 53, pl. 9, figs. 7, 8) from the Lower Karnian of Spiti is a small, three-ribbed form very similar to *S.* (*S.*) *ellesmerensis*. In this species, the valves are more strongly inflated, however, whereas the interarea is higher and aplanate (although Diener remarks that this feature is very variable in his species). In addition, the ribs are heavier, more angular and more widely spaced in the Himalayan form. The pedicle valve is much larger than the brachial valve and is conical. The dental plates are said to be weak in this species; the other internal features are not described.

Spiriferina (*S.*?) *avarica* Bittner (1890, p. 35, pl. 35, figs. 6, 7) from the Muschelkalk of Koveskalla in the Alpine Trias is known only from a pedicle valve and precise internal details appear to be lacking. However, this form has four to five lateral ribs and a rather narrow, shallow and rounded sulcus. The ribs are strongest in the umbonal region and become gradually obsolete towards the anterior margin.

Spiriferina (*S.*) *tyrolensis* Bittner (1890, p. 75, pl. 2, fig. 5) occurs in the same formation as the previous species and is similar in size and number of ribs to the Canadian form, but the costae are always very shallow and narrow, whereas the sulcus is broad and the crest of the opposing fold is angular.

The Rhaetic species "*Spiriferina*" *uncinata* Schafh. and "*Spiriferina*" *austriaca* Suess bear an external resemblance to *S.* (*S.*) *ellesmerensis*, but possess a cyrtinoid internal structure. Douglas (1929, p. 642) remarks that Persian examples of "*S.*" *uncinata* are intermediate between *Cyrtina* and *Spiriferina*.

Occurrence. The species occurs rather commonly (seven complete specimens, twenty fragments) in the Schei Point Formation, Canyon Fiord, Ellesmere Island (GSC loc. 28431). Also in the same formation near East Cape, Canyon Fiord (eighteen complete, seventeen fragments) (GSC loc. 28759). In Schei Point Formation, *Nathorstites* bed, Northern Table Island (GSC loc. 30353), three complete specimens only.

Age. Ladinian (possibly Karnian).

Spiriferina (Spiriferina) shalshalensis Bittner

Plate II, figures 1-9; Text-figures 4d, 7B

1891 *Spiriferina lilangensis* Stol. var. Griesbach, p. 143.

1899 *Spiriferina shalshalensis* Bittner, Bittner, p. 42, pl. 4, fig. 1.

1924 ?*Spiriferina* sp. nov. aff. *shalshalensis* Bittner, Krumbeck, p. 160, pl. 180(2), fig. 18a-c.

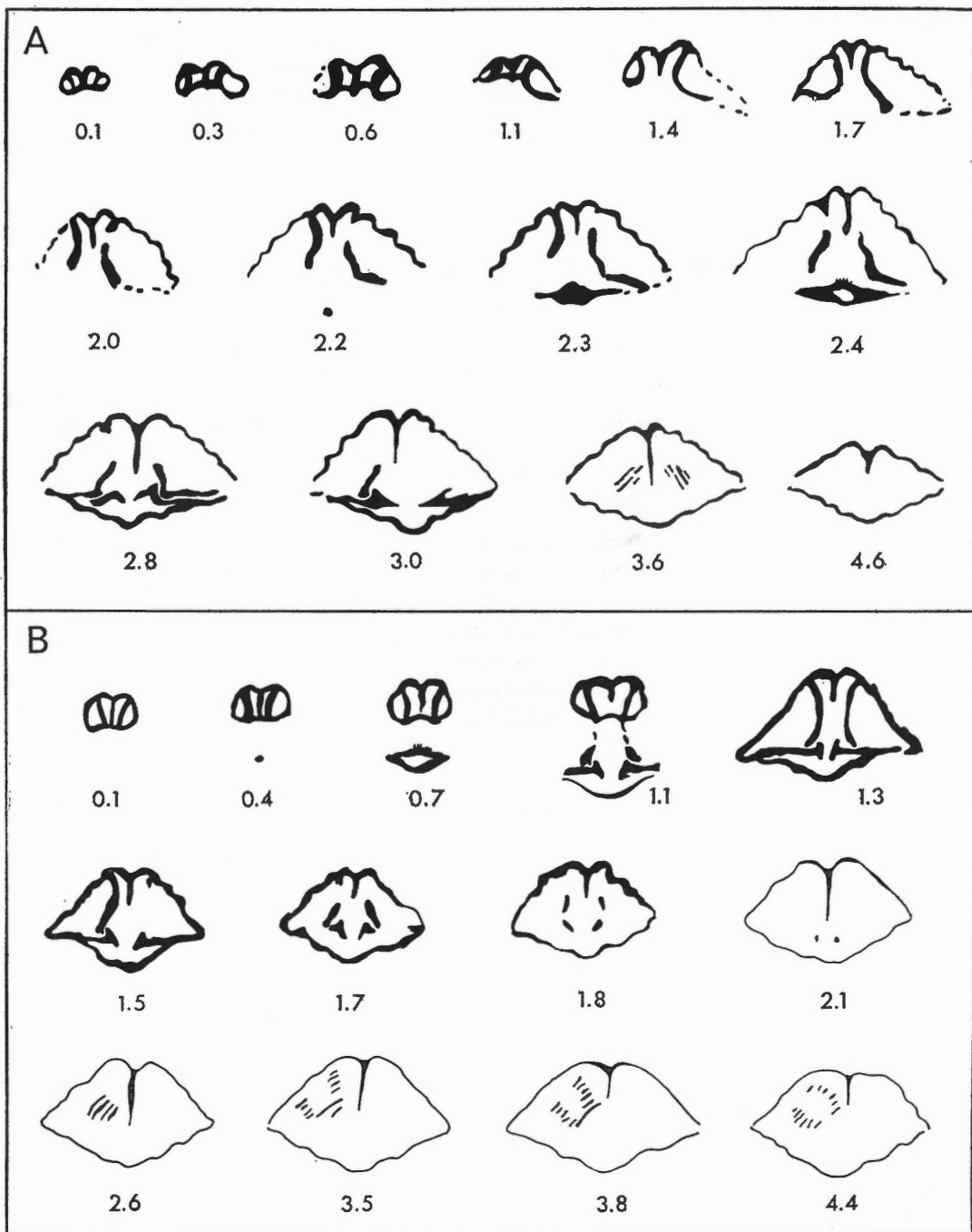
Diagnosis. Shell small, pedicle valve more convex than brachial valve, which is small, lid-like and rather flattened; hinge line straight, forming greatest width of shell (megathyrid), shell slightly wider than long. Cardinal interarea large and triangular, sharply delimited antero-laterally by angular ridges, wider than high, surface flat; beak only slightly incurved; interarea orthocline to apsacline and longitudinally striate. Delthyrium triangular, open or covered; delthyrial angle 21 to 33 degrees.

A relatively narrow, rather deep and angular median sulcus in the pedicle valve is flanked by five to seven subangular lateral costae on either side, which are complete, extending from anterior margin to umbo. Umbo of brachial valve small and incurved over a very narrow triangular interarea; notothyrium not seen. Fold of brachial valve narrow, occasionally a fine median furrow in the fold. Shell substance endopunctate.

Interior of pedicle valve with median septum extending over half length of valve, septum blade-like but not highly recurved, anteriorly concave, with growth lamellae. Dental plates strong, divergent, joining septum at apex of valve; strong teeth present, with corresponding sockets in small valve. Brachial valve interior with laminated cardinal process; spiralia with at least nine volutions in each spire; jugum not seen.

Types and dimensions.

Specimen	Locality	Lp	Lb	W	T	
Holotype	GSI 6375	Himalayas	10.6	6.8	(12.0)	6.9
Hypotype 1	20383	55535	9.5	6.2	12.3	5.9
Hypotype 2	20384	55535	9.4	—	—	—
Hypotype 3	20385	55535	9.2	6.7	10.5	7.2
Hypotype 4	20386	55535	8.5	6.0	11.6	6.0
Hypotype 5	20387	55535	9.3	7.4	9.8	6.4
Hypotype 6	20388	55535	9.0	7.3	10.8	6.5
Hypotype 7	20389	55535	9.0	7.0	11.4	6.5
Hypotype 8	20390	55535	(11.0)	—	13.0	—



TEXT-FIG. 7A, B. A. *Spiriferina* (*S.*) *ellesmerensis* n. sp. Camera lucida drawings of serial transverse sections, x2; distances in mm from apex of umbo; GSC loc. 28759/2.

B. *Spiriferina* (*S.*) *shalshalensis* Bittner. Camera lucida drawings of serial transverse sections, x2. GSC loc. 55535/12.

Remarks. The holotype of Bittner's species was originally collected and described as *Spiriferina lilangensis* Stol. var. by Griesbach in 1891 from the Upper Trias of the Shalshal section, near Rimkin Paiar, Himalayas. Bittner (1899) later erected this specimen as holotype of his species *Spiriferina shalshalensis*, recognizing its non-identity with the holotype of *S. lilangensis* Stol. Griesbach's specimen is in the Geological Survey of India collections (GSI 6375) and a plaster replica was kindly supplied by that institution (GSC No. 20392). Although most of the Canadian representatives have a slightly wider sulcus, there is no doubt of their identity with the Indian form. A specimen described as *S. sp. nov. aff. shalshalensis* Bittner by Krumbeck (1924) from the Trias of Pualaca, Timor is questionably referred to this species.

The species is homeomorphic after the Devonian cyrtinid *Cyrtina hamiltonensis* (Hall) recently re-described by Ehlers (1963); however, it lacks the typical pedicle opening of the Devonian form. Post-neanic atrophy of the pedicle stalk may have enabled the Triassic form to adopt a free-living mode of life, perhaps resting on the flat interarea of the pedicle valve in a manner similar to that suggested for the Devonian *Syringospira* and *Sphenospira* by Cooper (1954), i.e., with the sharp apex of the pedicle valve facing the prevailing water current direction. This is in direct contrast to the mode of life of the other species of *Spiriferina* from the Canadian Arctic which presumably lay on their large valve in a more or less horizontal position.

Occasional specimens of the Canadian *S. (S.) shalshalensis* (about one in ten) show a marked asymmetry (i.e., Pl. II, fig. 8a-e). Asymmetry of a similar kind in the Devonian *Spinocyrtia iowensis* was described by Ager and Riggs (1964), who attributed differences in the widths of the sides of the shell mainly to distortion due to overcrowding of individuals on the sea-floor. A similar situation may have prevailed in the Triassic forms—the effect is certainly not a post-mortem one.

Comparisons. *Spiriferina (S.) manca* Bittner (1890, p. 30, pl. 35, figs. 12-16) from the Koveskalla Muschelkalk, must be regarded as an extremely close relative. It has a broad, flat interarea of orthocline curvature, but the brachial valve is almost flat. There are four to five rounded ribs on each flank, whereas the fold in the small valve is rather angular.

Spiriferina (S.) canavarica Tommasi, as described by Bittner (1890, p. 32, pl. 35, figs. 17-20) from the Muschelkalk of Recoaro in the Alps, shares with *S. (S.) shalshalensis* the feature of the large, flat interarea, but the Alpine form has a unicastate sulcus fold region.

Spiriferina (S.) lilangensis Stoliczka (1866, p. 38, pl. 3, fig. 4) is based on two specimens from Lilang on the Lingti River, in the Lilang Series of Middle Triassic age. One of Stoliczka's original specimens was later re-described and re-figured by Bittner (1899, p. 20, pl. 4, fig. 2). The species has a broad interarea which is slightly concave and apsacline, and two discrete deltidial plates cover the delthyrium. There are seven or eight lateral ribs; the brachial valve is much larger and more convex than in *S. (S.) shalshalensis*.

Occurrence. In the Canadian Arctic, *S. (S.) shalshalensis* has so far been found only in the Schei Point Formation at Cape With, Canyon Fiord, Ellesmere Island (GSC loc. 55535).

Age. Karnian.

Subgenus *Rastelligera* Hector, 1879

Type species. *Rastelligera elongata* Thomson 1913 (ex. Hector MS.), by subsequent designation. The holotype is preserved in the collection of the New Zealand Geological Survey and comes from NZGS locality 363, Hokonui Hills (Otapirian) (Cat. No. BR 1064).

Diagnosis. *Spiriferina*, in which the interareas and hinge margins of the two valves are denticulate and interlock with one another.

Remarks. The subgenus *Rastelligera* was first mentioned by Hector in 1878 (p. 10) in his provisional notes on the Otapiri Series of Rhaetic age in New Zealand. He remarked upon the abundance of brachiopods in this formation ("chiefly peculiar forms"), including *Psioidea*, *Clavigera*, and *Rastelligera*, but cited no species of these subgenera. In 1879 (p. 538), Hector described *Rastelligera* as follows: "The hinge-line is enormously long in proportion to the height of the shell, and along the hinge-margin both valves are minutely denticulate, with rake-like teeth that appear to interlock. The proper dental processes are only feebly developed, if not altogether absent, and both valves are nearly equally convex. The genus *Rastelligera*, of which there are several species, is limited to the Wairoa Series (Triassic) and the Otapiri Series (Rhaetic)". Again, no nominal species were associated with the subgenus; Hector evidently intended to publish a full paper, with subgeneric and specific designations, sometime in the early 1880's, but the work never appeared (although the plates were prepared) and *Rastelligera* thus became a "genus caelebs." Meanwhile the manuscript name continued to be published—McKay (1881, p. 44) listed *Rastelligera taylori* Hector (a "nomen nudum", as it is another manuscript name) from the Otapirian of the Maitara River; Hector himself (1886) published figures of an unnamed species of *Rastelligera*.

Thomson (1913, p. 50) was concerned over the validity of Hector's "genera caelibia" and printed Hector's unpublished plates, with identifications "fide" McKay, in an attempt to clarify the situation. He was the first reviewer to associate a nominal species, i.e., *R. elongata* Hector MS. (pl. 2, fig. 8), with *Rastelligera* and this species is therefore the type species. Thomson also discussed the question of the type locality of *R. elongata* as follows: "The chirotype of *R. elongata* cannot be so certainly identified. It is probably a specimen from loc. 368, 'Trigonia Beds, slopes of southern peak of Benmore, Hokonui Hills, Southland (Rhaetic)', collected by McKay in 1878."

Trechmann (1917, p. 215) was openly sceptical about the value of Hector's subgenera; concerning *Rastelligera*, he doubted the generic value of the rake-like teeth along the hinge area, stating that, in fact, the same feature occurs in several Palaeozoic forms and is partly, at least, the result of weathering before fossilization. Trechmann described three new species with traces of a denticulate interarea, viz., *Spiriferina gypaetus*, *S. acutissima*, and *S. diomedea*, but rejected Hector's subgenus *Rastelligera*.

Thomson (1919), having laboured to resurrect the subgenera in 1913, was naturally averse to having them discarded by Trechmann four years later. He regarded Trechmann's species *S. diomedea* as synonymous with *Rastelligera elongata*, and noted (p. 413) that "Trechmann's explanation of the comb-tooth structure . . . does not appear convincing."

New Zealand palaeontologists have since followed Thomson in continuing to use the names *Psioidea*, *Clavigera*, and *Rastelligera*, although European workers have been more cautious, e.g., Paeckelmann (1931) questionably assigned all three forms to the subfamily Spiriferininae, but stated that "these three from the Australian Trias are known so insufficiently that, for the time being, nothing can be said about their close systematic assignation and independence." Allan (1945, p. 17) attributed *Rastelligera* to Thomson and designated *R. elongata* as type species, including *S. diomedea* Trech. within the synonymy of this species. Marwick (1953, p. 41) regarded Hector's three subgenera as valid and discussed the legal aspects for their retention. *R. elongata* Hector, 1913 (sic) was cited by Marwick as type species; the same author associated the denticulate nature of the hinge margin with elongation of the wings and was in favour of this feature as a useful external character which is not induced by weathering and is therefore of genetic origin. The type locality of *R. elongata* was given as "G.S. 363, Benmore Yards, near the junction of Bastion Burn with Winton Creek, Hokonui Hills."

Campbell (1956; 1959; 1960; Campbell and McKellar, 1956) has recently used the subgeneric name *Rastelligera* in his precise definitions of the stages of the Otapirian (Rhaetic), Warepan (Norian), and Otamitan (Upper Karnian) in the Trias of the Hokonui Hills, New Zealand.

Validity. *Rastelligera* has been used to describe alate *Spiriferina* with a denticulate hinge margin, in much the same way as Dagys (1963) has separated the denticulate *Zugmayerella* from the non-denticulate *Lepismatina* and *Laballa*. It is tempting to correlate the denticulation with progressive elongation of the hinge line, as Marwick has done, but it is obvious that a species such as *S. (R.) canadensis* n. sp., a typically brachythyrid-to-megathyrid form, belies such a generality. The feature is undoubtedly one which has been developed independently by species of several genera at different times in the history of the spiriferoids and appears to bear no relationship to any other feature, external or internal; however, it is believed that it has at least subgeneric value, although it is debatable whether it has any full generic distinction. It is therefore proposed to group those members of *Spiriferina* in which a true denticulate hinge margin is present into the subgenus *Rastelligera*.

Hector's subgenera *Clavigera* (= *Hectoria* Trechmann) and *Psioidea* differ so markedly from *Spiriferina* D'Orbigny, as here defined, that it is advisable to regard them as separate genera.

Spiriferina (*Rastelligera*) *canadensis* n. sp.

Plate III, figures 1-7; Plate IV, figures 1-8; Text-figures 3, 4b, 5 and 8

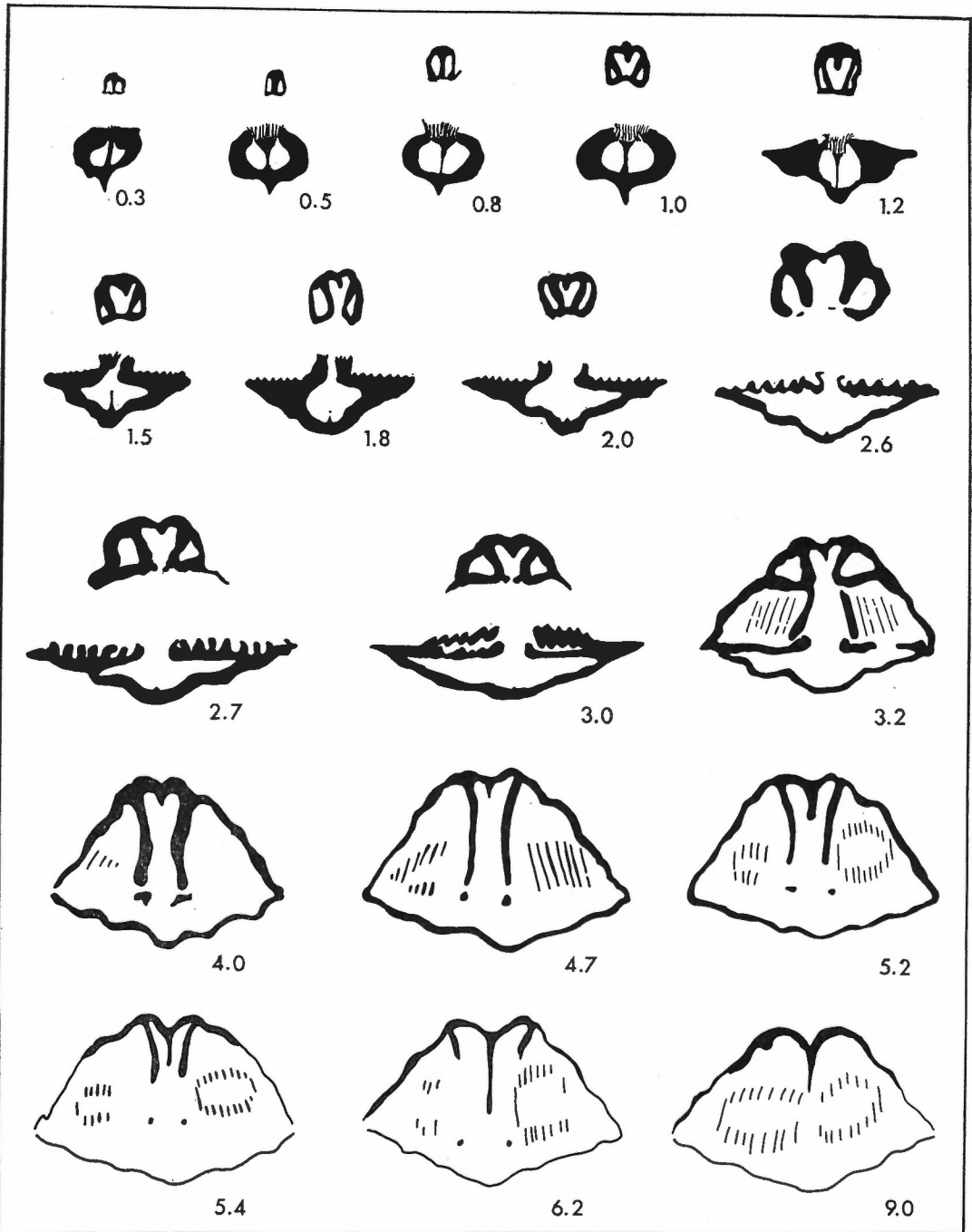
Diagnosis. Shell medium to large, pedicle valve more convex than brachial valve, hinge line straight, outline brachythyrid. Cardinal interarea of large valve triangular, wider than high, flat or gently concave, apsacline to procline but typically catacline, with incurved beak. In the large variety of this species, the flat palintrope is sharply delimited on the postero-lateral sides by an angular ridge (Pl. IV, fig. 4a-c). Interarea of thick layer of transversely striate shell material, with hinge margins of both valves denticulate and interlocking. Delthyrium triangular, open or covered; delthyrial angle 32 to 35 degrees.

Median sulcus of pedicle valve U-shaped, wide and flattened; lateral costae shallow and rounded to deep and subangular, usually three or four on either flank and extending from anterior margin to umbo. Umbo of brachial valve small, incurved over narrow interarea, apparently lacking notothyrium. Fold of brachial valve wide and flattened at its crest, sides angular with floor. Shell endopunctate.

Euseptoid median septum in interior of pedicle valve extends for about half length of valve and is highly recurved, terminating sharply. Dental plates thick, strong, and divergent, joining septum at apex of valve. Strong teeth fit into dental sockets in the small valve. In brachial valve a laminated cardinal process is present, supported by a dorsal median septum. Spiralia each of at least ten volutions; no jugum seen.

Types and dimensions.

Specimen	Locality	Lp	Lb	W	T	
Holotype	20393	32370	21.7	18.3	24.9	12.4
Paratype 1	20394	32370	21.8	19.2	24.6	15.0
Paratype 2	20395	32370	15.8	13.3	21.8	10.5
Paratype 3	20396	32370	17.6	15.6	22.7	12.0
Paratype 4	20397	32370	—	—	—	—
Paratype 5	20398	32370	16.8	15.9	24.4	10.7
Paratype 6	20399	32370	17.4	15.4	21.7	11.2
Paratype 7	20400	32370	17.0	13.1	18.8	10.0
Paratype 8	20401	32370	21.6	18.0	(21.7)	13.9
Paratype 9	20402	32370	22.0	18.3	28.0	11.3
Paratype 10	20403	55472	—	—	21.0	—
Paratype 11	20404	55520	30.0	—	(34.6)	—
Paratype 12	20405	55528	(31.4)	—	(37.7)	—
Paratype 13	20406	32370	—	29.7	(42.0)	—



TEXT-FIG. 8. *Spiriferina (Rastelligera) canadensis* n. sp. Camera lucida drawings of serial transverse sections, x2; distances in mm from apex of umbo; GSC No. 20407.

Remarks. The species is homeomorphic after North American representatives of *Psioidea* Hector (*see* Cooper, 1944, pl. 140, figs. 52-55). However, the internal structure of that genus is quite different from that of *Spiriferina* (Logan, 1964b).

Comparisons. No species of *Spiriferina* known to the author closely resembles this form from the Canadian Arctic. *Spiriferina* cf. *haueri* Suess described by Diener (1908, p.136, pl. 24, figs. 3-5) from the Rhaetic Megalodon Limestone of Spiti has a similar size and outline but possesses ten to twelve very fine radial costae on each flank of the sulcus fold region.

Occurrence. The species is relatively abundant in the Upper Calcareous Member of the Blaa Mountain Formation at the northwest mouth of Emma Fiord, Ellesmere Island (GSC loc. 32370). Other specimens in this formation were obtained from Raanes Peninsula (GSC loc. 55554); the section west of Hare Fiord (GSC locs. 55520 and 55528); the Sawtooth Range, Fosheim Peninsula (GSC loc. 55458); and the south side of Hare Fiord (midway in fiord) (GSC loc. 28762). In the Schei Point Formation of northern Raanes Peninsula, two isolated examples have been obtained (GSC locs. 55472 and 55478).

Age. Karnian.

Spiriferina (Rastelligera) lundgreni Boehm

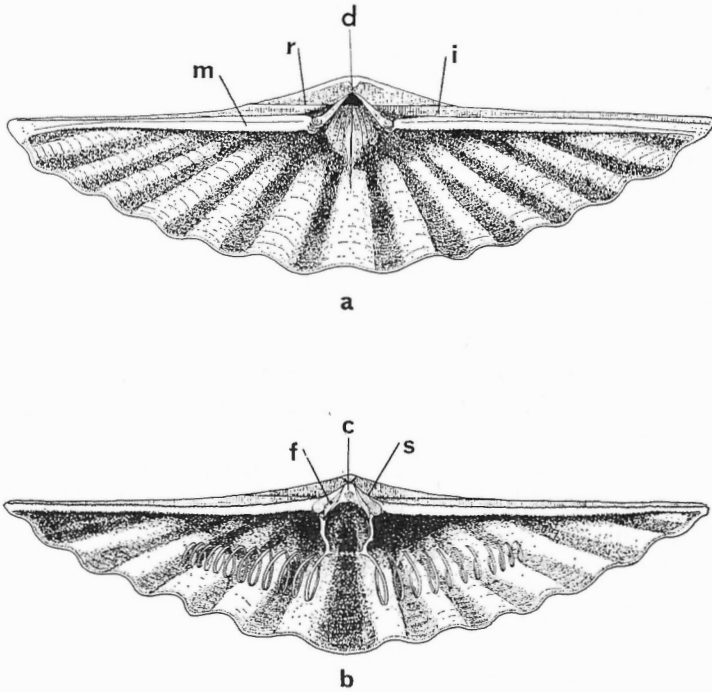
Plate V, figures 1-14; Text-figures 4a, 9

1903 *Spiriferina lundgreni* Boehm, p. 13, pl. 1, fig. 28.

Diagnosis. (All letters in parentheses refer to Text-fig. 9.) Shell small to medium, equally biconvex; hinge line straight, extremely alate or megistothyrid in outline, with greatest width at the hinge line. Cardinal extremities much produced and pointed. Cardinal interarea (i) of pedicle valve catacline and slightly curved, with pedicle valve beak incurved over interarea. Cardinal ridges (r) angular and linear; junction between cardinal interarea and vertical hinge margin (m) also angular. Cardinal interarea longitudinally and transversely striate, the transverse striae dominant, producing denticulate hinge margins in both valves which appear to interlock. Delthyrium triangular and probably closed by a single flat or convex plate (pseudodeltidium (d)). Delthyrial angle variable, 40 to 68 degrees.

Pedicle valve with smooth, U-shaped median sulcus, varying in depth and width; lateral costae rounded to subangular, typically six on each flank in both valves, with occasional signs of a faint rib at the lateral extremities; costae complete, extending from anterior margin to umbo. Brachial valve furnished with a small, rounded, incurved umbo and a long, narrow cardinal interarea, almost vertical, with angular cardinal ridges and sharp junction between interarea and hinge margin. Triangular notothyrium present; broad, smooth fold corresponds to median sulcus of opposite valve.

Shell endopunctate, with limited development of concentric growth lamellae, especially near anterior margins.



TEXT-FIG. 9a, b. *Spiriferina (Rastelligera) lundgreni* Boehm. Reconstruction of interior of (a) pedicle valve, (b) brachial valve, x3. i = cardinal interarea, r = cardinal ridge, m = hinge margin, s = outer socket ridge, f = inner socket ridge, c = cardinal process, d = delthyrial plate.

Internally, delthyrial cavity of pedicle valve has a strong median septum, which extends for about half the length of the valve and is concave anteriorly, terminating in a sharp, blade-like projection, not recurved. Median septum thickened at its base, where it joins floor of valve; dental plates weak, thin and poorly developed, attached to floor of valve for only a short distance. Median septum and dental plates converge to meet at the umbo. Plates support strong, bulbous teeth that fit into corresponding sockets in the opposite valve. Median septum flanked on either side by one (or possibly two) sets of longitudinally striated, pear-shaped to oval, adductor muscle impressions. Brachial valve interior with small, laminated cardinal process (c) which appears to be completely unsupported by any median septum. Strong, linear, divergent dental sockets are strengthened on their outer edge by a raised socket plate or ridge (s); the raised inner edges (f) are similar supporting ridges, and appear to represent the outer plates of a divided hinge plate (Cooper, 1944). An inner plate is not seen and was presumably never present. Two curved, dorsally convex, slightly inwardly directed crura issue from beneath the sockets, but do not appear to be definitely united by a jugum. Spiralia with twelve to fourteen volutions in each outwardly directed spire; no sign of pectination on the anterior face.

Types and dimensions.

Specimen		Locality	Lp	Lb	W	T
Holotype	Br 976	Spitsbergen	7.5	—	(18.3)	—
Hypotype 1	20408	28430	8.5	8.1	29.0	6.1
Hypotype 2	20409	28430	7.5	7.0	22.4	6.0
Hypotype 3	20410	28430	4.5	4.3	12.0	2.5
Hypotype 4	20411	28430	6.8	(6.6)	(28.0)	5.0
Hypotype 5	20412	28430	—	—	—	—

Remarks. The holotype, which is housed temporarily in the Museum of Comparative Zoology at Harvard (RM Cat. No. Br 976), is preserved in a dark grey calcareous limestone from the Upper Trias of Tschermaksberg, Spitsbergen (Pl. V, fig. 14). Despite its incomplete extremities, it is regarded as conspecific with the Canadian examples. An impression of a pedicle valve to the lower left of the holotype (Pl. V, fig. 14) shows more clearly the long hinge line typical of the Canadian specimens. Boehm (p. 14), notes a fragment of interarea furnished with vertical striation, apparently similar to the denticulation of the Canadian form.

Comparisons. Alate spiriferinids are uncommon, but the Canadian form may be compared with *Spiriferina* (*R.*) *lindstroemi* Boehm from the Upper Triassic of Urdsberg, Spitsbergen (Boehm, 1903, p. 12, pl. 1, figs. 24-27). Examination of the plastotype shows five lateral ribs, rather more widely spaced and angular than in *S.* (*R.*) *lundgreni*. In addition, the length of the shell to the width is proportionately greater in the species from Urdsberg.

Some of the alate varieties of *Spiriferina* (*S.*) *stracheyi* (Salter), described by Bittner (1899, p. 18, pl. 4, figs. 3-14, especially figs. 9, 10, and 14) from the Himalayan Triassic are similar to *S.* (*R.*) *lundgreni*, but the Indian form is much larger and more robust, and the ribbing is feebly developed. Diener (1907, p. 2, pl. 1, fig. 6) illustrates a large and very alate example from the Muschelkalk of Lilang and, like Bittner, compares it with "*Spiriferina*" *alata* from the European Zechstein. However, as this species lacks a true ventral median septum and is impunctate, it is referable to the genus *Pterospirifer* Dunbar. Westermann (1962) has recently recorded *Spiriferina* (*S.*) *stracheyi* from the Middle Triassic of British Columbia and Alberta, including highly acute "mature" forms of relatively large size. However, none of these authors notes any sign of a denticulate hinge margin.

S. (*S.*) *kaneharai* Yabe and Shimizu (1927, p. 135, pl. 13 (4), fig. 17a-b) from the *Monophyllites* zone, Rifu, Japan, has an alate outline, but is much larger, lacks denticles and has a very short median septum.

Spiriferina sp. described by Dagens (1963, p. 112, pl. 15, figs. 1-3) from the Upper Triassic of the northwestern Caucasus, U.S.S.R. was compared by that author with *S. lundgreni* from Spitsbergen. The Russian species shows faint ribbing and lacks the widely extended hinge line of the Canadian form. A denticulate hinge margin was not recorded by Dagens in his species.

Occurrence. *S. (R.) lundgreni* has been recorded only from the Schei Point Formation of Canyon Fiord, Ellesmere Island (GSC loc. 28430).

Age. Ladinian-Karnian.

?*Spiriferina (Rastelligera)* sp. indet.

Plate I, figures 10a-b

A large punctate spiriferoid showing traces of a denticulate hinge margin was obtained from the *Gryphaea* bed, Schei Point Formation, Cape With, Canyon Fiord, Ellesmere Island (Karnian) (GSC loc. 55539). Of three specimens collected, specimens 20381 and 20382 were incomplete, but showed traces of punctae in the shell. Only half of figured specimen 20380 is preserved, but shows part of the hinge margins and internal callosities of the two valves (Pl. I, fig. 10a-b). In addition, fragments of four large specimens from the *Gryphaea* bed, Schei Point Formation, Sawtooth Range, Fosheim Peninsula (GSC loc. 55459) were tentatively assigned to this group. The specimens are partly silicified and all traces of punctae have disappeared; however, there are signs of a transversely striated interarea.

Because of the small number of specimens and their state of preservation, it is impossible to assign this form to any particular species with certainty.

Age. Karnian.

LOCALITY INDEX

(Numbers 1-16 correspond with those in Text-fig. 1. Loc. 6 is NW of the limits of the Figure)

GSC Locality

1. 28430 Schei Point Formation (Ladinian or Karnian), about 20 miles SE of Cape Lockwood, Canyon Fiord, Ellesmere Island (Greely Fiord west area 340B).
Tozer 1956
Spiriferina (Rastelligera) lundgreni
Rhynchonelloids indet.
2. 28431 Schei Point Formation (Ladinian or Karnian), about 20 miles SE of Cape Lockwood, Canyon Fiord, Ellesmere Island (Greely Fiord west area 340B).
Tozer 1956
Spiriferina (Spiriferina) ellesmerensis
Rhynchonelloids indet.
3. 28759 Schei Point Formation (Ladinian), 25 miles SE of Cape Lockwood, Canyon Fiord, Ellesmere Island (Greely Fiord west area 340B). Thorsteinsson 1956
Spiriferina (S.) ellesmerensis
4. 28762 Blaa Mountain Formation, Upper Calcareous Member (Karnian), south side of Hare Fiord, midway in fiord, Ellesmere Island (Greely Fiord west area 340B).
Thorsteinsson 1956
Spiriferina (Rastelligera) canadensis
5. 30353 Schei Point Formation, *Nathorstites* bed (Ladinian), 80 feet above *Daonella frami* bed, north coast of Table Island (Cornwall Island area 59C). Tozer 1957
Spiriferina (S.) ellesmerensis var.
6. 32370 Blaa Mountain Formation, Upper Calcareous Member (Karnian), northwest mouth of Emma Fiord, Ellesmere Island (Cape Stallworthy area 560D).
Thorsteinsson 1957
Spiriferina (Rastelligera) canadensis
7. 55458 Schei Point Formation (?Karnian), "Sawtooth Range", Fosheim Peninsula, Ellesmere Island, 79°47'N, 83°15'W (Canyon Fiord area 49H).
Round Valley Oil Co. 1961
Spiriferina (Rastelligera) canadensis
Terebratuloids, rhynchonelloids, indet.
8. 55459 Schei Point Formation, *Gryphaea* bed (Karnian), Sawtooth Range, Fosheim Peninsula, Ellesmere Island, 79°47'N, 83°15'W (Canyon Fiord area 49H).
Round Valley Oil Co. 1961
?Spiriferina (Rastelligera) sp. indet.

9. 55472 Schei Point Formation, *Gryphaea* bed (Karnian), northern Raanes Peninsula, south of Gretha Islands, Ellesmere Island 78°50'N, 85°02'W (Eureka Sound South area 49F). Round Valley Oil Co. 1961
Spiriferina (Rastelligera) canadensis
10. 55478 Schei Point Formation (Ladinian or Karnian), northern Raanes Peninsula, south of Gretha Islands, Ellesmere Island, 78°50'N, 85°02'W (Eureka Sound South area 49F). Round Valley Oil Co. 1961
Spiriferina (Rastelligera) canadensis
11. 55520 Blaa Mountain Formation, Middle Slide Member (Karnian), section west of Hare Fiord, Ellesmere Island, 80°40'N, 87°45'W (Greely Fiord west area 340B). Round Valley Oil Co. 1961
Spiriferina (Rastelligera) canadensis var.
12. 55528 Blaa Mountain Formation, Upper Calcareous Member (Karnian), section west of Hare Fiord, Ellesmere Island, 80°40'N, 87°45'W (Greely Fiord west area 340B). Round Valley Oil Co. 1961
Spiriferina (Rastelligera) canadensis var.
13. 55535 Schei Point Formation (probably Karnian), Cape With, Canyon Fiord, Ellesmere Island (Greely Fiord west area 340B). Round Valley Oil Co. 1961
Spiriferina (S.) shalshalensis
14. 55539 Schei Point Formation, *Gryphaea* bed (Karnian), Cape With, Canyon Fiord, Ellesmere Island (Greely Fiord west area 340B). Round Valley Oil Co. 1961
?Spiriferina (Rastelligera) sp. indet.
15. 55554 Blaa Mountain Formation, probably Lower Calcareous Member (Karnian), east of Trappers Cove, Raanes Peninsula, Ellesmere Island (Eureka Sound south area 49F). Round Valley Oil Co. 1961
Spiriferina (Rastelligera) canadensis
16. 55571 Schei Point Formation (Karnian), Sawtooth Range, Fosheim Peninsula, Ellesmere Island, 79°18'N, 84°16'W (Eureka Sound north area 49G). Round Valley Oil Co. 1961
Spiriferina (Rastelligera) canadensis

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PLATES I TO V

PLATE I

(All figures natural size, except where otherwise stated)

Spiriferina (Spiriferina) ellesmerensis n. sp. (Page 19)

- Figures 1a-e. Holotype, GSC No. 20373. Ventral, dorsal, anterior, posterior, and side views.
- Figures 2a-e. Paratype 1, GSC No. 20374. Ventral, dorsal, anterior, posterior, and side views.
- Figures 3a, b. Paratype 2, GSC No. 20375. 3a, posterior view; 3b, detail of posterior view to show endopunctae and delthyrium; x3.
- Figures 4a, b. Paratype 3, GSC No. 20376. 4a, posterior view of pedicle valve; 4b, interior of same valve, showing median septum and dental plates; both $\times 1\frac{1}{2}$.
- Figure 5. Paratype 4, GSC No. 20377. Recurved median septum of pedicle valve; x3.
- Figures 6a-e. Paratype 6, GSC No. 20379. Ventral, dorsal, anterior, posterior, and side views.
- Figures 7a, b. Paratype 5, GSC No. 20378. Ventral and dorsal views of elongate variety.

Spiriferina (Spiriferina) mansfieldi Girty (Page 20)

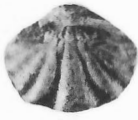
- Figures 8a-e. Topotype, USNM 147421. Ventral, dorsal, anterior, posterior, and side views. Lower Triassic, Ross Fork Limestone, Thaynes Group, Idaho, U.S.A. (USGS Girty green-label locality 7879).
- Figures 9a, b. Topotype, USNM 147422. Ventral and posterior views. Lower Triassic, Ross Fork Limestone, Thaynes Group, Idaho, U.S.A. (USGS Girty green-label locality 7879).

Spiriferina (Rastelligera) sp. indet. (Page 31)

- Figures 10a, b. GSC No. 20380. Posterior, and side view of interior, showing internal callosity and dental plate.



1a



1b



1c



1d



1e



2a



2b



2c



2d



2e



3b



4a



4b



5



3a



6a



6b



6c



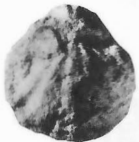
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6e



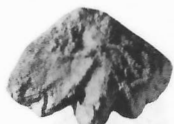
7a



7b



8a



8b



8e



8c



8d



10a



10b



9a



9b



1a



1b



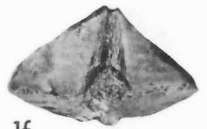
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1d



1e



1f



2a



2b



3a



3b



3c



4a



4b



4c



4d



4e



5a



5b



5c



5d



5e



6a



6b



6c



7



8a



8b



8c



8d



8e



9a



9b



9c



9d



9e

PLATE II

(All figures natural size, except where otherwise stated)

Spiriferina (Spiriferina) shalshalensis Bittner (Page 21)

- Figures 1a-f. Hypotype 1, GSC No. 20383. Ventral, dorsal, anterior, posterior, and side views. 1f, detail of interarea and delthyrium; $\times 2$.
- Figures 2a, b. Hypotype 2, GSC No. 20384. Ventral and anterior views; $\times 1\frac{1}{2}$.
- Figures 3a-c. Hypotype 6, GSC No. 20388. Ventral, dorsal, and anterior views; $\times 1\frac{1}{2}$.
- Figures 4a-e. Hypotype 3, GSC No. 20385. Ventral, dorsal, anterior, posterior, and side views; $\times 1\frac{1}{2}$.
- Figures 5a-e. Hypotype 4, GSC No. 20386. Ventral, dorsal, anterior, posterior, and side views; $\times 1\frac{1}{2}$.
- Figures 6a-c. Hypotype 5, GSC No. 20387. Ventral, dorsal, and anterior views; $\times 1\frac{1}{2}$.
- Figure 7. Hypotype 8, GSC No. 20390. Ventral view; $\times 1\frac{1}{2}$.
- Figures 8a-e. Hypotype 7, GSC No. 20389. Ventral, dorsal, anterior, posterior, and side views of an asymmetrical example; $\times 1\frac{1}{2}$.
- Figures 9a-e. Plaster replica of holotype, GSI No. 6375, GSC No. 20392. Ventral, dorsal, anterior, posterior, and side views. Upper Trias, Shalshal section, near Rimkin Paiar, Himalayas. (Karnian)

PLATE III

(All figures natural size, except where otherwise stated)

Spiriferina (Rastelligera) canadensis n. sp. (Page 26)

- Figures 1a-e. Holotype, GSC No. 20393. Ventral, dorsal, anterior, posterior, and side views.
- Figures 2a-e. Paratype 1, GSC No. 20394. Ventral, dorsal, anterior, posterior, and side views.
- Figures 3a-c. Paratype 2, GSC No. 20395. Ventral, dorsal, and anterior views.
- Figure 4. Paratype 4, GSC No. 20397. Recurved median septum of pedicle valve; x3.
- Figures 5a-f. Paratype 3, GSC No. 20396. Ventral, dorsal, anterior, posterior, and side views, 5f, detail of interarea; x2.
- Figures 6a-c. Paratype 7, GSC No. 20400. Ventral, dorsal, and anterior views.
- Figures 7a-c. Paratype 6, GSC No. 20399. Ventral, dorsal, and anterior views.



1a



1b



1c



1d



1e



2a



2b



2c



2d



2e



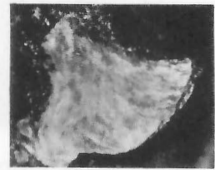
3a



3b



3c



4



5a



5b



5c



5d



5e



6a



6b



6c



5f



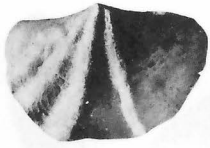
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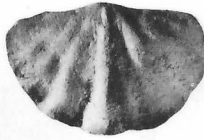
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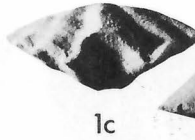
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1a



1b



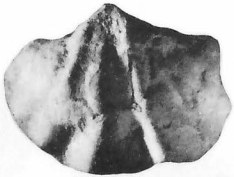
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1d



1e



2a



2b



2c



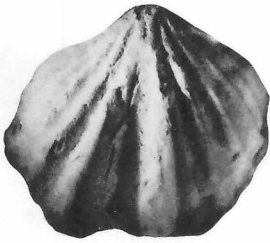
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3b



3c



4a



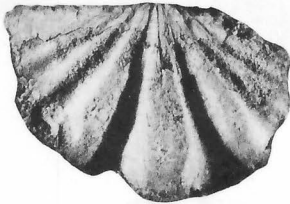
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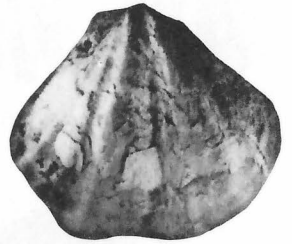
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7

PLATE IV

(All figures natural size, except where otherwise stated)

Spiriferina (Rastelligera) canadensis n. sp. (Page 26)

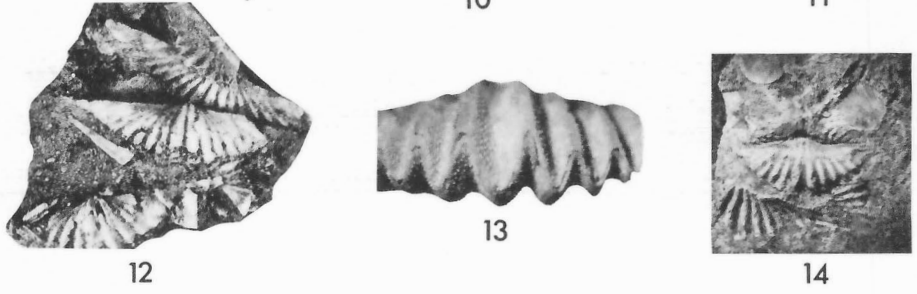
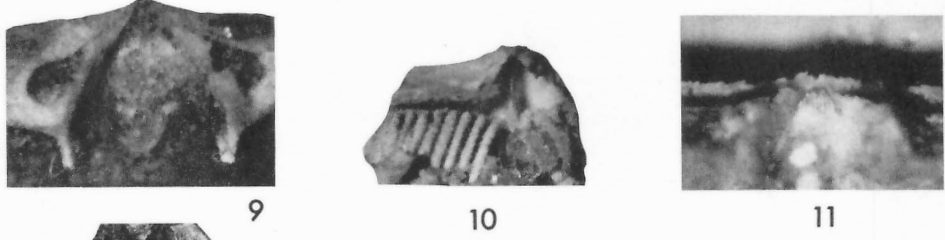
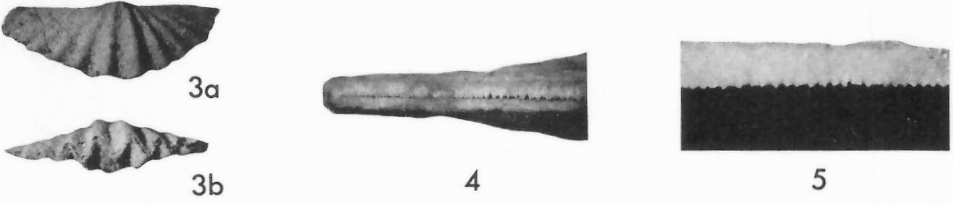
- Figures 1a-e. Paratype 5, GSC No. 20398. Ventral, dorsal, anterior, posterior, and side views.
- Figures 2a-c. Paratype 8, GSC No. 20401. Ventral, dorsal, and anterior views.
- Figures 3a-c. Paratype 9, GSC No. 20402. Ventral, dorsal, and anterior views.
- Figures 4a-c. Paratype 11, GSC No. 20404. Ventral, side, and posterior views of pedicle valve of large variety.
- Figure 5. GSC No. 20407. To show hinge area of valves, denticulate hinge margins, and cardinal process; x3.
- Figure 6. Paratype 13, GSC No. 20406. Brachial valve of large variety, with reflection of dorsal median septum on exterior.
- Figure 7. Paratype 12, GSC No. 20405. Pedicle valve of large variety.
- Figure 8. Paratype 10, GSC No. 20403. Interarea of pedicle valve; x2.

PLATE V

(All figures natural size, except where otherwise stated)

Spiriferina (Rastelligera) lundgreni Boehm (Page 28)

- Figures 1a-e. Hypotype 1, GSC No. 20408. Ventral, dorsal, anterior, posterior, and side views.
- Figures 2a-e. Hypotype 2, GSC No. 20409. Ventral, dorsal, anterior, posterior, and side views.
- Figures 3a, b. Hypotype 3, GSC No. 20410. Ventral and anterior views; x2.
- Figure 4. Hypotype 4, GSC No. 20411. Hinge margins near extremities of both valves; x5.
- Figure 5. Hypotype 5, GSC No. 20412. Denticulate hinge margin of pedicle valve; x6.
- Figure 6. Hypotype 4, GSC No. 20411. Hinge margins and delthyrium; x7.
- Figure 7. Hypotype 5, GSC No. 20412. Hinge structures of pedicle valve; x5.
- Figure 8. Hypotype 6, GSC No. 20413. Pedicle valve, to show tooth, dental plate, delthyrium, and posterior end of pseudodeltidium; x8.
- Figure 9. Hypotype 7, GSC No. 20414. To show dental sockets and crura of brachial valve; x8.
- Figure 10. Hypotype 8, GSC No. 20415. Spiralia; x4.
- Figure 11. Hypotype 9, GSC No. 20416. Cardinal process of brachial valve; x6.
- Figure 12. Hypotype 10, GSC No. 20417. Shell coquina.
- Figure 13. Hypotype 11, GSC No. 20418. Anterior margin and infillings of punctae; x5.
- Figure 14. Holotype, R. M. Cat. No. Br 976. Pedicle valve and impressions. Upper Trias, Tschermaksberg, Spitsbergen.



BULLETINS

Geological Survey of Canada

Bulletins present the results of detailed scientific studies on geological or related subjects. Some recent titles are listed below (Queen's Printer Cat. No. in brackets):

- 126 Feldspar and quartz phenocrysts in the Shingle Creek porphyry, British Columbia, by H. H. Bostock, 1966, \$2.00 (M42-126)
- 127 Ordovician Ostracoda from Lake Timiskaming, Ontario, by M. J. Copeland, 1965, \$2.00 (M42-127)
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- 129 Structural evolution and plutonism in Valhalla gneiss complex, British Columbia, by J. E. Reesor, 1965, \$3.25 (M42-129)
- 130 The copper content of Canadian Shield rocks, Red Lake-Lansdowne House area, northwestern Ontario, by R. F. Emslie and R. H. C. Holman, 1966, 90 cents (M42-130)
- 131 The Permian ammonoids of Arctic Canada, by W. W. Nassichuk, W. M. Furnish, and B. F. Glenister, 1965, \$2.00 (M42-131)
- 132 The Cretaceous Smoky Group, Rocky Mountain Foothills, Alberta and British Columbia, by D. F. Stott, 1967, \$3.75 (M42-132)
- 133 Upper Devonian stromatoporoids from the Redwater Reef Complex, Alberta, by J. E. Klovan; Upper Devonian stromatoporoids from southern Northwest Territories and northern Alberta, by C. W. Stearn, 1966, \$4.50 (M42-133)
- 134 Contributions to Canadian palaeontology: Part I, Trilobites from Upper Silurian rocks of the Canadian Arctic Archipelago, *Encrinurus (Frammia)* and *Hemiarges*; Part II, Ordovician and Silurian tabulate corals *Labyrinthites*, *Arcturia*, *Troedssonites*, *Multisolenia*, and *Boreastor*; Part III, A new species of *Hemicystites*, by T. E. Bolton and G. Winston Sinclair, 1965, \$2.50 (M42-134)
- 135 Type lithostrotionid corals from the Mississippian of western Canada, by E. W. Bamber, 1966, \$1.50 (M42-135)
- 136 Surficial geology of Dawson, Larsen Creek, and Nash Creek map-areas, Yukon Territory, by P. Vernon and O. L. Hughes, 1966, \$1.00 (M42-136)
- 137 A geochemical method of correlation for the Lower Cretaceous strata of Alberta, by E. M. Cameron, 1966, \$1.35 (M42-137)
- 138 Reconnaissance of the surficial geology of northeastern Ellesmere Island, Arctic Archipelago, by R. L. Christie, 1967, \$1.65 (M42-138)
- 139 Groundwater studies in the Assiniboine River drainage basin, by Peter Meyboom: Part I, The evaluation of a flow system in south-central Saskatchewan, 1966, \$2.00 (M42-139); Part II, Hydrologic characteristics of phreatophytic vegetation in south-central Saskatchewan, 1967, \$1.65 (M42-139/2)
- 140 Silurian brachiopods and gastropods of southern New Brunswick, by A. J. Boucot, *et al.*, 1966, \$3.00 (M42-140)
- 141 Geology and structure of Yellowknife Greenstone Belt, by J. F. Henderson and I. C. Brown, 1967, \$2.50 (M42-141)
- 142 A comprehensive study of the Preissac-Lacorne batholith, Abitibi county, Quebec, by K. R. Dawson, 1966, \$2.00 (M42-142)
- 143 Ferromagnesian silicate minerals in the metamorphosed iron-formation of Wabush Lake and adjacent areas, Newfoundland and Quebec, by K. L. Chakraborty, 1966, \$1.00 (M42-143)
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- 145 Part I—Stratigraphy and structure of southeastern Prince Edward Island; Part II—Surficial Geology, by Larry Frankel, 1967, \$2.00 (M42-145)
- 146 The Devonian Cedared and Harrogate Formations in the Beaverfoot, Brisco, and Stanford Ranges, southeastern British Columbia, by H. R. Belyea and B. S. Norford, 1967, \$2.00 (M42-146)
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- 152 Lower Cretaceous Bullhead and Fort St. John Groups, between Smoky and Peace Rivers, Central Rocky Mountain Foothills, Alberta and British Columbia, by D. F. Stott *in press*
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