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SYSTEMATIC DESCRIPTIONS, PALEOECOLOGY AND CORRELATIONS OF THE LATE PALEOZOIC SUBFAMILY *SPIRIFERELLINAE* (BRACHIOPODA) FROM THE YUKON TERRITORY AND THE CANADIAN ARCTIC ARCHIPELAGO

J.B. WATERHOUSE
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Canada

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Preface

This report presents detailed descriptions of brachiopods that are widespread in upper Paleozoic rocks of the Yukon and the Canadian Arctic Archipelago and provides benchmarks for applications of detailed paleontological studies to other fields of geology.

The study shows that some species lived in a wide range of environments, whereas others occupied only muddy and silty seafloors. Some forms were restricted geographically and others ranged widely. Certain brachiopods were strongly affected by climate and, for example, avoided the glaciated regions of the time. This new knowledge of the time ranges and habitats of these important brachiopods will aid in the correlation of upper Paleozoic rocks throughout North America, a sequence that is important in northern Canada for its resource potential.

R.A. Price
Director General
Geological Survey of Canada

OTTAWA, December 1982

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Abstract

Sixteen species of the brachiopod subfamily Spiriferellinae Waterhouse are described from the Upper Carboniferous and Early to Middle Permian beds of the Yukon Territory and the Canadian Arctic Archipelago. New taxa are *Spiriferella primaeva* n. sp., *S. yukonensis* n. sp., *S. leviplica* n. sp., *Eridmatus petita* n. sp., *Elivina cordiformis* n. sp., *Plicatospiriferella canadensis* n. gen., n. sp., and *Alispiriferella ordinaria* (Einor) n. gen. The remaining species are all shared with the Soviet Union and/or Arctic islands such as Greenland and Spitzbergen, apart from the poorly known species *S. arctica* (Haughton). *Spiriferella tibetana* of Chernyshev not Diener in the Urals is renamed *Elivina tschernyschewi*, and *Spiriferella saranae* Chernyshev not de Verneuil is renamed *S. barkhatovae* n. sp.

It is shown that pustules formed on the shell surface at roughly weekly intervals and that mature shells lived for up to four years. Some species tolerated a wide range of lithofacies, whereas others were restricted to a muddy or silty seafloor. A few spiriferellin species commonly were sympatric: *Alispiriferella ordinaria* (Einor) with *S. saranae* (de Verneuil), and *Timaniella harkeri* Waterhouse with *Spiriferella loveni* (Diener) or *S. keilhavii* (von Buch). The common species were relatively long lived through three to four brachiopod zones and moderately widespread over the globe. They also tolerated some range in temperature, but they avoided glaciated regions near the South Pole in east Australia, the highly saline Zechstein Sea, and paleotropical realms such as Armenia and China, though appearing at some paleotropical horizons in Laos, Fergana and Texas. A summary of world distribution and interrelationships shows several major lineages in *Spiriferella*. The predominant one included the widespread *Spiriferella saranae* (de Verneuil), which may have evolved later into two other widespread species, *S. keilhavii* (von Buch) and *S. rajah* (Salter). Another, less dominant, lineage with short incurved umbo included *Spiriferella pseudodraschei* Einor and other forms restricted to the Northern Hemisphere. Yet another suite of species with round-crested fold (*S. wimani*) ranged into both hemispheres. *Eridmatus* Branson was chiefly a Middle and Late Carboniferous genus of limited distribution, closely allied to *Spiriferella*. *Elivina* Frederiks was of modest significance but ranged widely, whereas the short-lived Middle Permian genus *Timaniella* Barkhatova was restricted to the Northern Hemisphere. *Alispiriferella* also was limited to the Northern Hemisphere, as was *Plicatospiriferella*.

Résumé

Seize espèces de brachiopodes de la sous-famille Spiriferellinae Waterhouse, provenant de dépôts du Carbonifère supérieur et du Permien inférieur et moyen du Territoire du Yukon et de l'archipel Arctique canadien, sont décrits. Les nouveaux taxons sont: *Spiriferella primaeva* esp. n., *S. yukonensis* esp. n., *S. leviplica* esp. n., *Eridmatus petita* esp. n., *Elivina cordiformis* esp. n., *Plicatospiriferella canadensis* gen. n., esp. n. et *Alispiriferella ordinaria* (Einor) gen. n. Les autres espèces se retrouvent en Union soviétique ou dans des îles de l'Arctique comme le Groenland et le Spitzberg, à l'exception de l'espèce mal connue *S. arctica* (Haughton). *Spiriferella tibetana* de Chernyshev et non Diener, dans l'Oural, est renommé *Elivina tschernyschewi*, et *Spiriferella saranae* Chernyshev et non de Verneuil est renommé *S. barkhatovae* esp. n.

On montre que des pustules se formaient sur la coquille à intervals d'une semaine environ et que les animaux vivaient jusqu'à quatre ans à maturité. Certaines espèces toléraient une grande variété de faciès lithologiques tandis que d'autres étaient restreintes aux fonds marins boueux ou silteux. Quelques espèces de Spiriferellinae étaient souvent sympatriques: *Alispiriferella ordinaria* (Einor) et *S. saranae* (de Verneuil); *Timaniella harkeri* Waterhouse et *Spiriferella loveni* (Diener) ou *S. keilhavii* (von Buch). Les espèces communes ont vécu relativement longtemps, dans trois ou quatre zones de brachiopodes, et étaient assez répandues à la surface du globe. Possédant une tolérance à une certaine marge de températures, elles évitaient toutefois les régions glaciaires antarctiques en Australie orientale, la mer très salée de Zechstein et certains domaines paléotropicaux (absentes en Arménie et en Chine, on les retrouve toutefois dans certains horizons paléotropicaux du Laos, de Fergana et du Texas). Un résumé de la distribution mondiale et des interrelations révèle plusieurs lignées importantes de *Spiriferella*. La plus importante comprend l'espèce très répandue *S. saranae* (de Verneuil), qui s'est peut être scindée pour donner *S. keilhavii* (von Buch) et *S. rajah* (Salter), également très répandues. Une lignée moins importante d'espèces à petit apex incurvé, comprenant *Spiriferella pseudodraschei* (Einor), est limitée à l'hémisphère nord. Une autre série d'espèces à pli à sommet arrondi (*S. wimani*) habitait les deux hémisphères. Le genre *Eridmatus* Branson, qui a vécu essentiellement au Carbonifère moyen et supérieur et avait une distribution restreinte, était étroitement allié à *Spiriferella*. *Elivina* Frederiks était peu important mais vastement distribué, tandis que le genre *Timaniella* Barkhatova, qui vécut peu longtemps au Permien moyen, était limité à l'hémisphère nord, comme les genres *Alispiriferella* et *Plicatospiriferella*.

SYSTEMATIC DESCRIPTIONS, PALEOECOLOGY AND CORRELATIONS OF THE LATE PALEOZOIC SUBFAMILY *SPIRIFERELLINAE* (BRACHIOPODA) FROM THE YUKON TERRITORY AND THE CANADIAN ARCTIC ARCHIPELAGO

INTRODUCTION

Species of the genus *Spiriferella* Chernyshev 1902 and its allies *Timaniella* Barkhatova 1968 and *Elivina* Frederiks 1919 are common in Middle to Upper Pennsylvanian and especially Permian deposits of the northern Yukon Territory and Canadian Arctic Archipelago. Haughton (1858) described *Spiriferella arctica* Haughton from Melville Island and Bathurst Island, collected during one of the searches for Sir John Franklin and Chernyshev and Stepanov (1916) recorded several forms from the limestone bluffs of Great Bear Cape, Ellesmere Island, collected during the second *Fram* Expedition from Norway. Three species were described by Harker and Thorsteinsson (1960) from Grinnell Peninsula, Devon island: *Spiriferella saranae* (de Verneuil) from both the Lower Permian Belcher Channel Formation (specimens here assigned to *S. pseudotibetana* Stepanov) and the Middle Permian Assistance Formation (specimens assigned herein to *S. loveni* (Diener)); Assistance species *Spiriferella keilhavii* (von Buch), here interpreted as *S. loveni* (Diener); and *Pterospirifer* sp. A, now assigned to *Timaniella harkeri* Waterhouse. Nelson and Johnson (1968) recorded a number of species of *Spiriferella* from the northern Yukon Territory: *Spiriferella saranae* (de Verneuil), *Spiriferella ordinaria* (Einor), *S. editiareatus* Einor, *S. keilhavii* (von Buch), and *S. rajah* (Salter). Their illustrations have allowed us to reinterpret some of the names, such as those shells assigned to *S. rajah*, but the assigned specific limits and especially ranges are difficult to understand.

The basic stratigraphic and faunal framework of upper Paleozoic rocks in the northern Yukon Territory was provided by Bamber and Waterhouse (1971), with the establishment of several formations and a number of brachiopod zones, on the basis of field work by officers of the Geological Survey of Canada during Operation Porcupine. Correlation was established by means of studies on small Foraminifera and Fusulinacea summarized by Mamet and Ross (in Bamber and Waterhouse, 1971), Ammonoidea by Nassichuk (1970, 1971 and in Nassichuk et al., 1965), and Brachiopoda by Waterhouse (1969, 1971a). Species of *Spiriferella* were listed and illustrated by Bamber and Waterhouse (1971), but their study was concerned primarily with generic ranges and significant species, so that little attention was paid to specific limitations of *Spiriferella*, apart from the description of *Timaniella harkeri* Waterhouse.

It is the purpose of this work to describe systematically the species of *Spiriferella* recorded by Bamber and Waterhouse (1971). Nearly half of the material examined here was collected by officers of the Geological Survey of Canada in the last 20 years from the Arctic and the Yukon, and the remainder was collected by J.B. Waterhouse and colleagues during expeditions to the northern Yukon Territory from 1968 to 1972. J. Waddington made an extensive initial survey of the material for her M.Sc. thesis, completed at the University of Toronto in 1972; Waterhouse then reexamined the material, using large new collections.

The bulk of the collections are housed at the Geological Survey of Canada, Ottawa, including many of the types. These are numbered serially with the prefix GSC. A second suite of specimens is housed at the Royal Ontario Museum, Toronto, and numbered serially with the prefix ROM.

Many of the fossil localities were collected by officers of the Geological Survey of Canada and are numbered serially with the prefix GSC or the prefix C- with a serial number. The remainder of the localities were collected by J.B. Waterhouse and assistants; they are numbered serially with the prefix JBW. All are described in the appendices. It is difficult to denote geographic limits in arctic terrain where place names are few and outcrops are extensive. But the sequence of GSC localities, enumerated in Appendix 1, is provided by Bamber (1972) in a tabulation of stratigraphic columns from the Yukon Territory, and many of the significant brachiopod zones are indicated on aerial photographs, especially for the important sections of the Peel River, the Tatonduk River, and the type Ettrain ridge of Bamber and Waterhouse (1971). The localities collected by Waterhouse will be described fully in forthcoming studies. Their location and sequential relationships are shown here in Figures 3, 4, 6 and 7, as summarized in Appendix 4.

Acknowledgments

This study is based on extensive and careful collecting by officers of the Geological Survey of Canada, including E.W. Bamber, P. Harker, W.W. Nassichuk, D.K. Norris and R. Thorsteinsson.

The authors particularly wish to acknowledge the loan of collections and provision of stratigraphic information facilitated by E.W. Bamber and W.W. Nassichuk, Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary. Help in our own field studies was provided by assistants F. Kerr, H. Reid, J. Scott, R. Zimmerman, A.E. Oldershaw, and I.S. Nichols. H. Brunton, British Museum (Natural History), London, kindly sent us a duplicate and photographs of *Spiriferella arctica* (Haughton), borrowed on our behalf from the Royal Dublin Museum.

The types of *Spiriferella* species from Indonesia were examined at Mineralogisch-Geologisch Instituut, Rijks Universitet, Utrecht (Hamlet, 1928), and at the Geologisch-paläontologisches Instituut und Museum, Bonn, with the help of G.H.R. von Koenigswald and H.K. Erben. The species of Spiriferellinae from the Indian subcontinent were examined principally at the Geological Survey of India, Calcutta, with the help of M.V.A. Sastry, and those from New Zealand at the New Zealand Geological Survey, through the courtesy of C.A. Fleming.

Examination of type specimens of *Spiriferella* from the Soviet Union and Spitzbergen, kept at the Chernyshev Museum, VSEGEI, Leningrad, was facilitated by D.L. Stepanov, University of Leningrad, and M.V. Kulikov, VSEGEI. Other material from the Soviet Union was shown to us by B.S. Abramov, VSEGEI, and H. Pavlova and T.A. Grunt, Paleontological Institute, Moscow. G. Thomas and N. Archbold, Department of Geology, University of Melbourne, kindly allowed us to examine their collections from Western Australia.

Photographs are by B. O'Donovan, and some of the maps and sections were drawn originally by F. Jurgenheit, both at the Department of Geology, University of Toronto. Expenses for field work and research were met by grants from the Department of Energy, Mines and Resources (DEMR D 13-4-37/73), the National Research Council of Canada (NRC grant 4263) and the Department of Indian and Northern Affairs.

STRATIGRAPHY AND CORRELATION

Northern Yukon Territory

Ettrain Formation

Carboniferous and Permian stratigraphy of the northern Yukon Territory is summarized by Bamber and Waterhouse

(1971). The first appearances of Spiriferellinae as *Spiriferella primaeva* n. sp. and *Plicatospiriferella canadensis* n. sp. are within dolomitic, calcareous siltstone and silty, calcareous, microcrystalline to finely crystalline dolomite of the Peel River area (Figs. 1, 4). The Peel beds are abundantly fossiliferous in bands 0.3 to 2 m thick, in which Productacea such as *Reticulatia*, *Umboanctus* and *Praehorridonia* are prominent, and specimens of choristitinids and other spiriferacean brachiopods are fairly numerous. Intervening siltier bands contain fewer shells. The beds were deposited as an inshore facies of the Ettrain Formation, which is a light grey weathering, skeletal limestone with dark beds and lenses of chert, found extensively over northern Yukon Territory. In the type Ettrain section 116F-9 of the northern Ogilvie Mountains (Figs. 1, 5-7) (Bamber and Waterhouse, 1971, Fig. 3), the top of the formation was placed, perhaps somewhat arbitrarily, above beds of the *Kozlowskia* brachiopod zone (Ck), in which bands of limestone alternate with three bands of shale, approximately 5 to 15 m thick. *Spiriferella primaeva* is found sparsely in carbonate of the *Gibbospirifer* Zone (Cgb) just below these shale members and also in siltstone of the Ettrain equivalents of the Tatonduk River to the south. *Spiriferella yukonensis* n. sp. occurs in one of the carbonate members in the *Kozlowskia* Zone (Ck).

Correlation. The age of the Ettrain Formation ranges from Bashkirian to Kasimovian, i.e., Morrowan to Missourian (Bamber and Waterhouse, 1971), judged from Foraminifera and Brachiopoda. The Peel River beds are Moscovian in age, as discussed by Bamber and Waterhouse (1971, p. 134), because they fall within the *Praehorridonia* Zone (Cp) of brachiopods, which is correlated with the *Gemmulicosta* Zone (Cg), bearing Foraminifera Zone 22 of Mamet, dated as early to middle Moscovian (see Mamet and Ross, in Bamber and Waterhouse, 1971, p. 204). Brachiopods of the *Praehorridonia* and *Gemmulicosta* zones are directly correlated with the Podol horizon, and those of the overlying *Purdonella* and *Gibbospirifer* zones are correlated provisionally with the Myachkovian horizon of the Moscow Basin.

New unnamed formation

A formation yet to be described and named lies above the Ettrain Formation and below the Jungle Creek Formation of Bamber and Waterhouse (1971). It is restricted to the northern Ogilvie Mountains, in the vicinity of Ettrain and Jungle creeks (Figs. 6, 7), and consists of yellow-weathering limestone, green siltstone, black shale, and quartz conglomerate and grits totalling about 400 m in thickness. Two sections in Bamber and Waterhouse (1971, Fig. 3) summarize the succession. In section 116F-16, the formation commences essentially at shale in the *Kozlowskia* Zone (Ck) and includes the covered interval just above the "Lower Member". The notation of the *Kozlowskia* Zone is changed here from Ck to Dk, as its newly incoming species persist through overlying D faunas. In section 116F-9, the formation includes the *Kozlowskia* Zone and persists up to about the upper conglomerate. (The designated zones Eta and Ey in Bamber and Waterhouse (1971) for this section were in error.)

Brachiopods, including *Spiriferella yukonensis* n. sp., are numerous throughout the formation and are like those described by Bamber and Waterhouse (1971) for the *Orthotichia-Septospirifer* Zone (Dos), with numerous schuchertellids, *Kozlowskia*, *Duartea*, *Psilocamara*, and choristitinids. The faunas await detailed examination, but they are likely to be of late Middle or Late Carboniferous age. The *Kozlowskia* Zone (Dk) is perhaps Kasimovian or early Gshelian, and the *Orthotichia-Septospirifer* (Dos) and overlying, as yet unnamed, zones are probably Gshelian and Orenburgian, if the latter subdivision is valid.

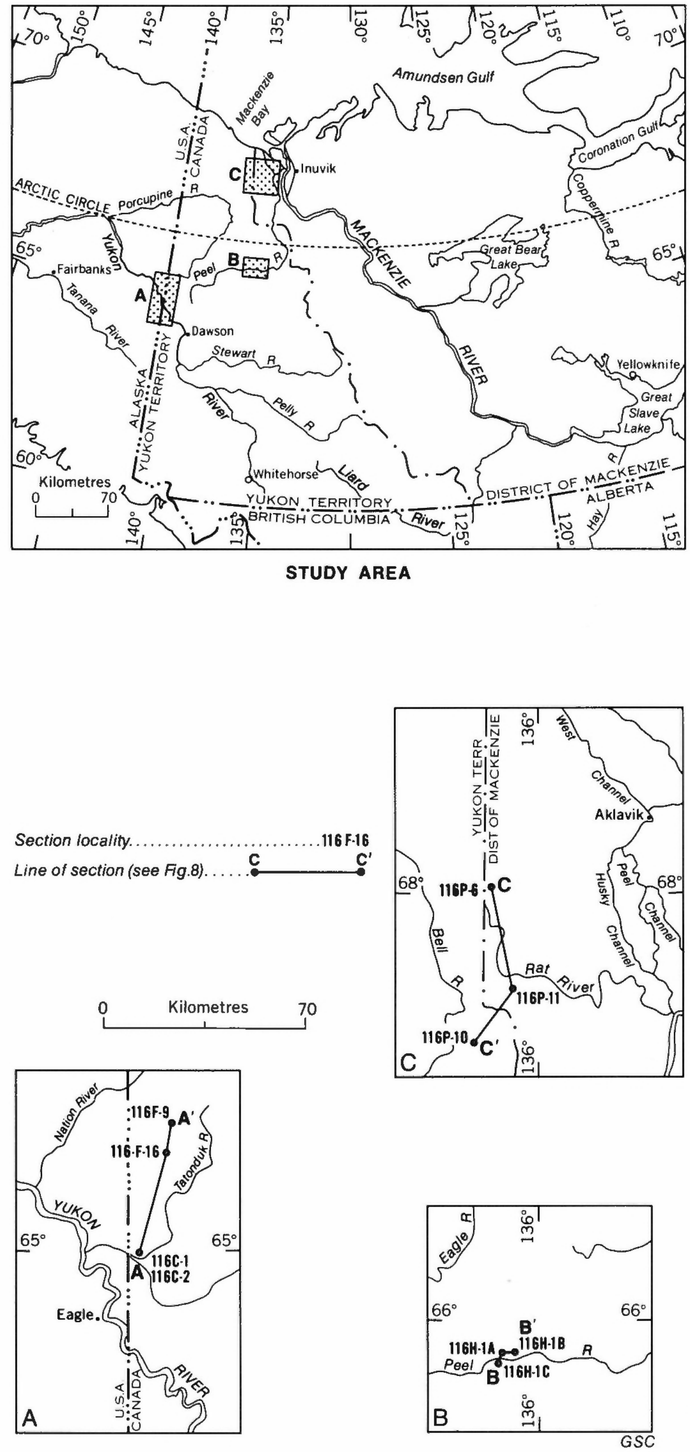

Figure 1. Map of northern Yukon Territory showing location of sections. (Modified from Bamber and Waterhouse, 1971, Fig. 1, 2.)

Jungle Creek Formation

The Jungle Creek Formation is predominantly a recessive unit of fine to moderately coarse clastic sediment, mainly slightly calcareous fine to medium sandstone, shale and siltstone, and some skeletal limestone, micritic-skeletal and spicular limestone, dolomite, chert conglomerate and siliceous mudstone. In the type section of the Tatonduk River, the lower part of the formation consists of conglomerate overlain by recessive silty shale containing brachiopods of the *Orthotichia-Septospirifer* Zone (Dos), including *Spiriferella yukonensis* n. sp. These beds are overlain by either a fault or a considerable unconformity through which Upper Carboniferous beds and faunas are missing. This gap was not realized by Bamber and Waterhouse (1971), who considered that the shale was overlain conformably by the *Tomiopsis-Attenuatella* Zone (Eta). The uppermost part of the formation comprises the *Jakutoproductus* Zone (Ej), which contains *Spiriferella saranae* (de Verneuil).

Fossiliferous sequences are exposed more abundantly farther north in the Ogilvie Mountains, near headwaters of the Ettrain and Jungle creeks. Here clastic beds of the basal Jungle Creek Formation overlie the new formation, discussed previously, with slight unconformity and contain two additional brachiopod zones, Eka and Eo, not seen in the Tatonduk sections (see Table 1). The beds are represented in most of the "upper member" of section 116F-16 of Bamber and Waterhouse (1971, p. 40, Fig. 3), together with younger beds up to and including the *Attenuatella* Zone (Ea). *Eridmatus petita* n. sp. is found in the lower three zones, and *Spiriferella pseudodraschei* Einor and *S. saranae* (de Verneuil) are found in the Ey through to Ej zones in this region (Figs. 6, 7).

In the southern Eagle Plain and Peel River area, the Jungle Creek beds lie unconformably on the Ettrain equivalents and total 400 m in thickness. The succession consists of brown-grey dolomite and siltstone and dolomitic calcareous siltstone, overlain by calcareous sandstone, with a thick black siltstone unit, containing the *Attenuatella* (Ea) and *Tornquistia* (Et) brachiopod zones. Overlying silty sandstone contains the *Jakutoproductus* Zone (Ej). *Alispiriferella ordinaria* (Einor) and *Spiriferella saranae* (de Verneuil) are found widely, and *S. p eudodraschei* Einor (Figs. 2, 3) is present.

Correlation. The Jungle Creek Formation accumulated mainly during the Asselian and Sakmarian ages of the Early Permian Period and includes Aktastinian faunas at the top. Seven brachiopod zones are known in the northern Ogilvie Mountains (Table 1), of which five were outlined by Bamber and Waterhouse (1971) and two were added to the basal part of the succession by Sarytcheva and Waterhouse (1972). The three basal zones belong to the Asselian Stage. In the Ogilvie Mountains, the base of the Permian is marked by the occurrence of *Attenuatella* and *Kochiproductus*. Various genera typical of the underlying formation disappeared, notably *Kozlowskia* and *Duartea*. The following *Orthotichia* Zone (Eo) is characterized by *Orthotichia*, *Neospirifer* and *Kutorginella*, with other genera, and the topmost *Attenuatella-Tomiopsis* Zone (Eta) has abundant *Attenuatella* and *Tomiopsis ovulum* Waterhouse, as described by Bamber and Waterhouse (1971). The faunas and the threefold subdivision suggest possible correlation with the Kurmain, Uskalik and Suren horizons of the Asselian Stage in the Ural Mountains (Likharev, 1966; Waterhouse, 1976). The basal zone is correlated also with the *Uddenites* Zone in the Gaptank shale in west Texas, i.e., upper Virgilian, and the following zones probably are equivalent to the Neal Ranch Formation (Wolfcampian) of Ross (1963) in the Glass Mountains of west Texas.

The overlying *Yakovlevia*, *Attenuatella*, *Tornquistia* and *Jakutoproductus* zones are correlated with the Tastubian, Sterlitamakian and Aktastinian substages of the Urals, chiefly on the basis of brachiopod species but with support from ammonites in the *Tornquistia* Zone (Et) described by Nassichuk (1971). We prefer to use the world standard classification for Permian correlation, based on Soviet sequences. The sequences of Texas have limited relevance to Permian brachiopod faunas of northern Canada and certainly are not a "North American standard".

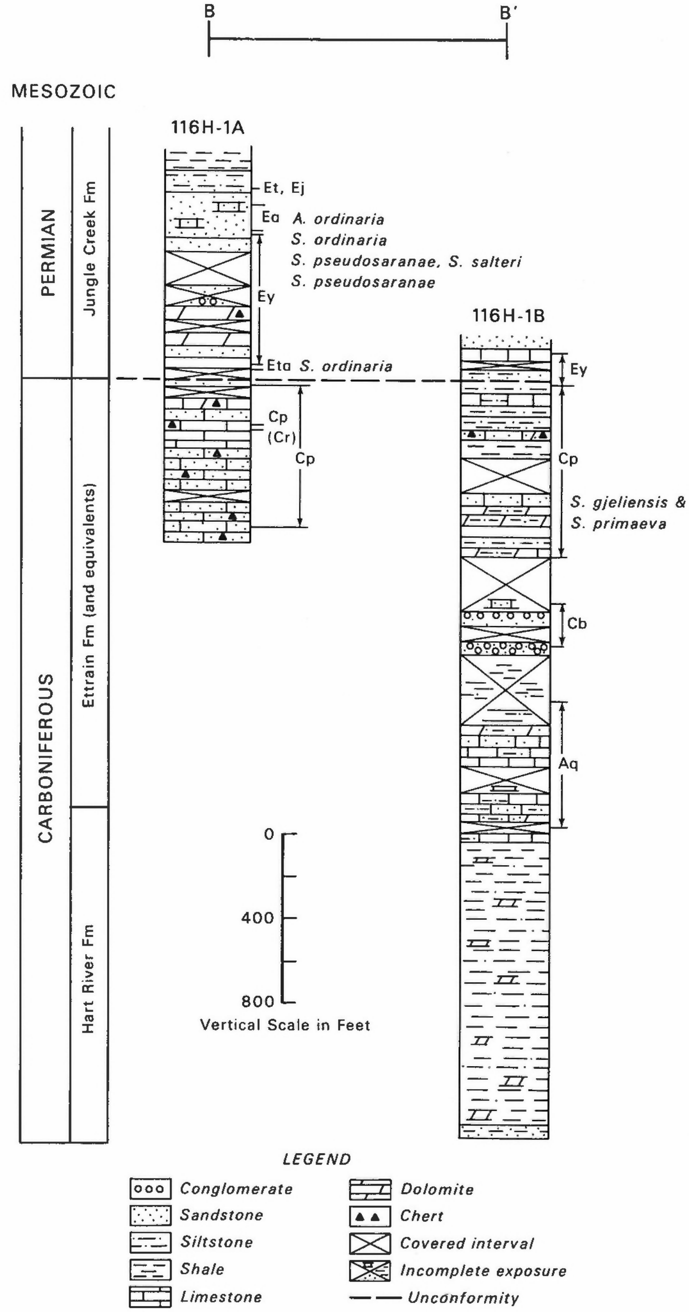

Figure 2. Stratigraphic columns, Peel River area (Fig. 1), with sequence of Spiriferellinae. (After Bamber and Waterhouse, 1971, Fig. 6)

Tahkandit Formation

The Tahkandit Formation of Mertie (1930; see also Brabb and Grant, 1971) in Alaska continues into the Yukon Territory. In the Tatonduk River section, this formation is about 440 m thick. The lower part, 170 m thick, comprises reddish brown skeletal limestone and calcareous chert-pebble conglomerate, and the upper part consists of spicular glauconitic chert with siltstone through the basal 50 m and limestone in the upper 120 m. To the northeast, the basal unit is missing, and limestone predominates over chert in the Sheep Mountain area. Farther north, the formation thins and near Jungle Creek the basal 20 m consist of fine sandstone and chert,

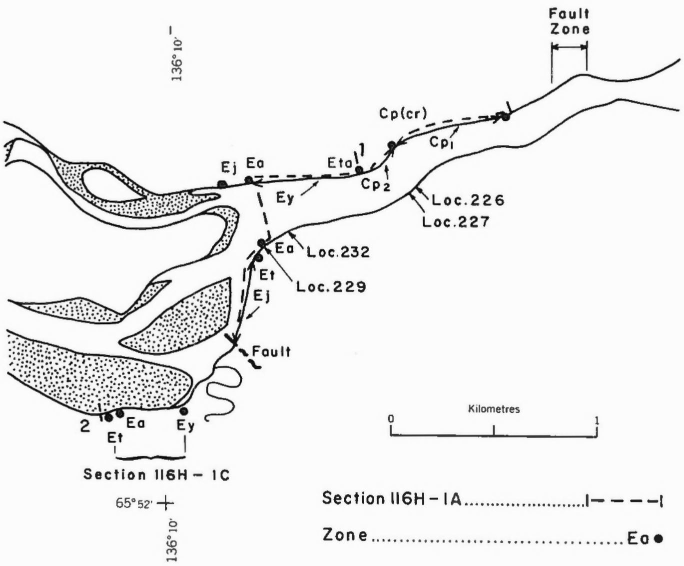

Figure 3. Fossil localities and brachiopod zones along the Peel River. (Redrawn from Bamber and Waterhouse, 1971, Fig. 4, from airphoto A13137-68, National Air Photo Library, Department of Energy, Mines and Resources.) (1) Contact between Ettrain and Jungle Creek Formations. (2) Cretaceous-Permian boundary. Brachiopod zones named in Table 1.

overlain by 80 m of skeletal limestone packed with brachiopods. To the northeast, the formation is more than 400 m thick, containing fine- to coarse-grained skeletal limestone and scattered chert (Bamber and Waterhouse, 1971, p. 69).

The lower Tahkandit beds in the Tatonduk River valley contain faunules of the *Antiquatonia* (Fa) and *Sowerbina* (Fs) zones. The brachiopods are correlated with those of the Baigendzinian Stage of the Urals and correlative faunas of Siberia and elsewhere, and they may prove to be approximately equivalent to the Sarginian and Krasnoufimian substages. *Spiriferella pseudotibetana* is found in the Tatonduk River area in both of these zones, and *S. vaskovskii* is present to the north at Mount Burgess in poorly dated beds. At Mount Burgess, Nelson and Johnson (1968) described numerous *Spiriferella* from the Tahkandit Formation, but it is not known which brachiopod zones are represented there.

Three brachiopod zones have been recognized in the middle and upper Tahkandit Formation: the *Pseudosyrinx* Zone (Fps) at the base, the *Thamnosia* Zone (Ft), renamed the *Thuleproductus* Zone by Sarytcheva and Waterhouse (1972), and the widespread *Cancrinelloides* Zone (Gc) at the top, found also at Sheep Mountain and in the area of Ettrain and Jungle creeks. *Spiriferella loveni* (Diener) is found in the Fps, Ft and Gc zones in the Tatonduk River area, and *S. keilhavii* is found in the same area in the Ft zone. The basal Fps zone is correlated with the Road Canyon fauna of the Glass Mountains, Texas, and the Filippovian Substage at the base of the Kungurian Stage in the Kama River region of

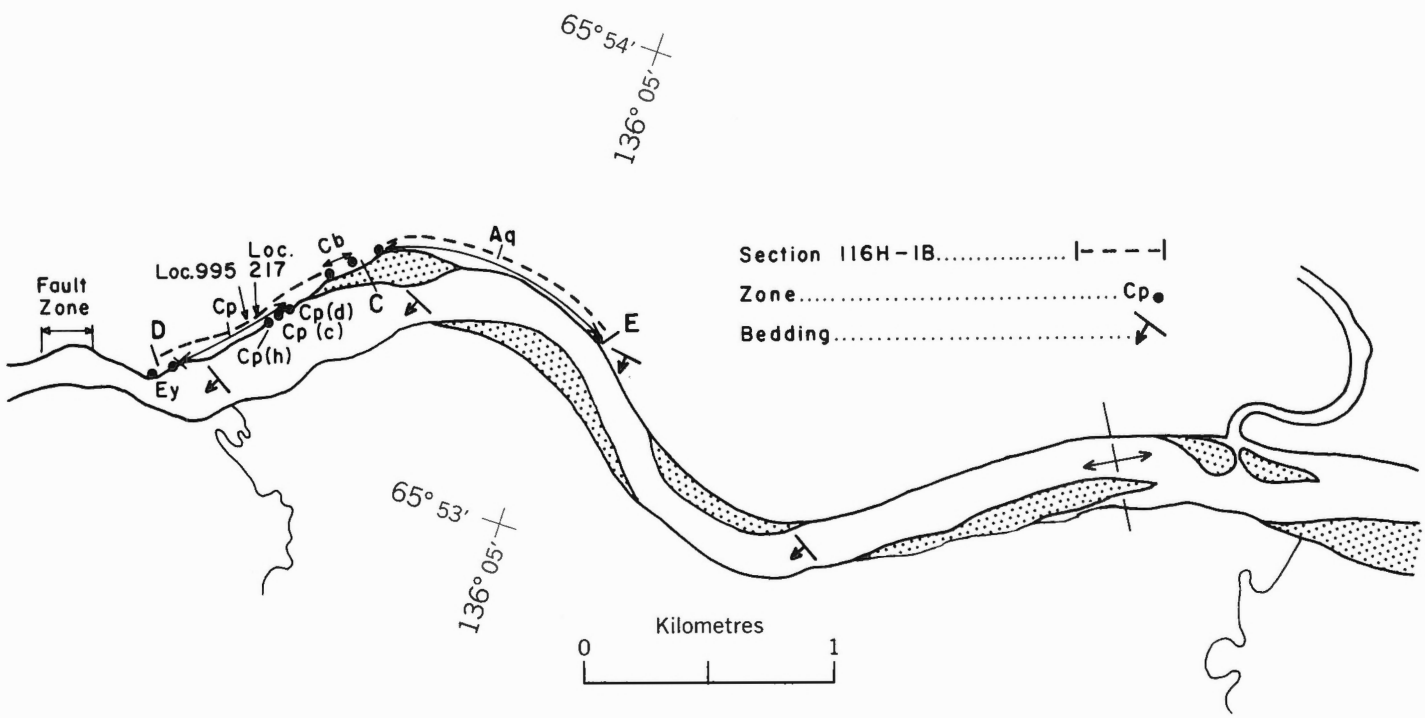

Figure 4. Fossil localities and brachiopod zones along the Peel River downstream (east) from Fig. 3. (Redrawn from Bamber and Waterhouse, 1971, Fig. 5, based on airphoto A14368-83, National Airphoto Library, Department of Energy, Mines and Resources.) (D) Base of Jungle Creek Formation. (D-C) Ettrain equivalents, and "Unit 2". (C-E) Hart River Formation. The Hart River Formation (upper Viséan) and Unit 2 (?early Moscovian) lack Spiriferellinids, though yielding numerous other brachiopods.

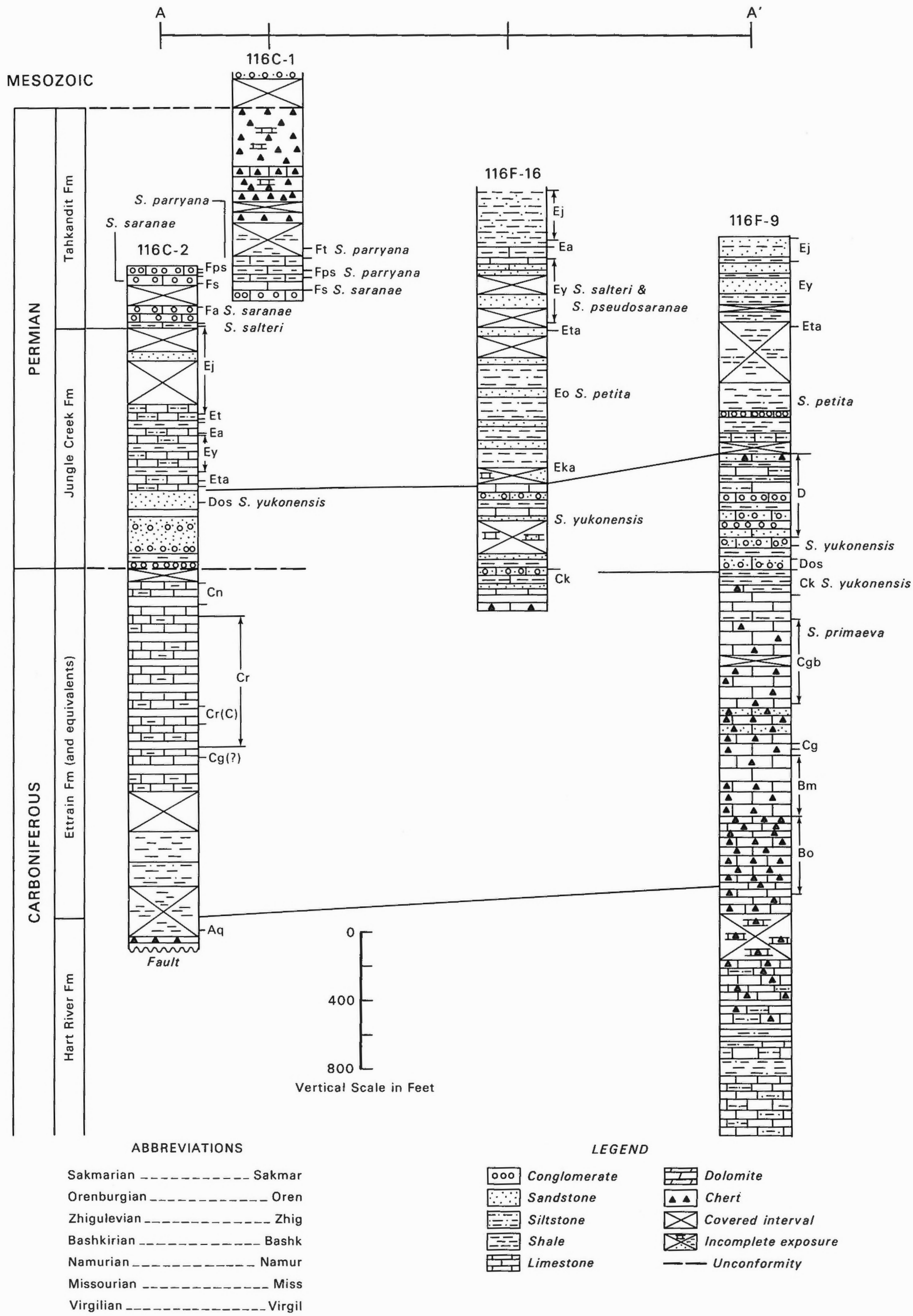

Figure 5. Stratigraphic columns, B-B[1] (see Fig. 1), northern Ogilvie Mountains, with principal sequence of Spiriferellinae. (Modified from Bamber and Waterhouse, 1971, Fig. 3.)

Russia (Zolotova et al., 1966), as discussed by Waterhouse (1976). Brachiopods of the *Thuleproductus* Zone (Ft) are correlated with the Nevolin level from the Kama River region in Russia, and the *Cancrinelloides* (Gc) fauna shares key genera, notably *Cancrinelloides* and *Licharewia*, with the lower type Kazanian (Kalinovian Substage) of the Russian Platform and related faunas of the Soviet Arctic.

Northern Richardson Mountains

The upper Paleozoic rocks of the northern Richardson Mountains (Fig. 8) are mainly Permian sandstone, shale and siltstone, with local carbonates. No formal names have yet been applied. In the Fish Creek - Cache Creek area, a sequence of Carboniferous limestone, dolomite and minor sandstone rests disconformably on Devonian or older rocks. These beds may represent an eastern extension of the Lisburne Group in the British-Barn mountains area to the west. The sequence is overlain conformably by Permian rocks: a basal carbonate unit, over 400 m thick, containing early Sakmarian brachiopods; a middle shale unit, 700 m thick; and an upper sandstone unit, 800 m thick, containing Kungurian and Kazanian brachiopods of zones Fn (=Fps), Fl (=Ft), and Gc (see Table 1). *Timaniella harkeri* Waterhouse is found in the Kungurian faunas. This sequence is overlain unconformably, with local angularity, by massive Jurassic sandstone.

To the south and east, in the Bell River - Rat River area, the Devonian Imperial Formation is overlain by a basal sandstone unit, 40 m thick, and an upper unnamed carbonate unit, 110 m thick. Both units are Early Permian in age, and *Spiriferella saranae* is found in each. *Spiriferella pseudodraschei* is present also in the sandstone. At Symmetry Mountain to the south, there are over 1000 m of Permian sediment consisting of basal sandstone and conglomerate, a middle shale unit and an upper sandstone unit with Kazanian brachiopods (zone Gc). *Elivina cordiformis* n. sp. is found in the shale unit. The Permian sequence is overlain unconformably by Jurassic rocks. *Timaniella harkeri* Waterhouse is found in Kungurian faunas at White Mountains.

Arctic Archipelago

Upper Paleozoic rocks of the Canadian Arctic Archipelago extend over the Sverdrup Basin and range in age from Early Carboniferous to Middle Permian (Kazanian). Permian rocks outcrop in Melville Island, Cameron Island, Grinnell Peninsula, Helena Island, western and northern Ellesmere Island and northern Axel Heiberg Island (Fig. 9, Table 2). This study includes *Spiriferella* and allies from all but Axel Heiberg Island, found in the Belcher Channel, Assistance, Trold Fiord, van Hauen and Degerböls formations. The Permian units generally are separated by disconformities or sharp contacts. Their relationships were mapped by Thorsteinsson (1974).

Belcher Channel Formation

The Belcher Channel Formation at the type locality on northern Grinnell Peninsula consists of quartzose sandstone and light grey, fossiliferous limestone with brachiopods, corals, and fusulines of Baigendzinian (Ej - Fs) age identified as Artinskian by Thorsteinsson (in Harker and Thorsteinsson, 1960). On Devon Island, the Belcher Channel Formation overlies the Pennsylvanian Canyon Fiord Formation and is overlain unconformably by the lower Kungurian or Filippovian, Assistance Formation. On Sabine Peninsula, northern Melville Island, the Belcher Channel Formation also overlies the Canyon Fiord Formation disconformably and is overlain by the Sabine Bay Formation, which contains ammonoids at its base. The most complete sections occur on western Ellesmere Island, between Bjorne Peninsula and Cañon Fiord, where the Belcher Channel Formation is 330 to 600 m thick and gradationally overlies the Canyon Fiord Formation.

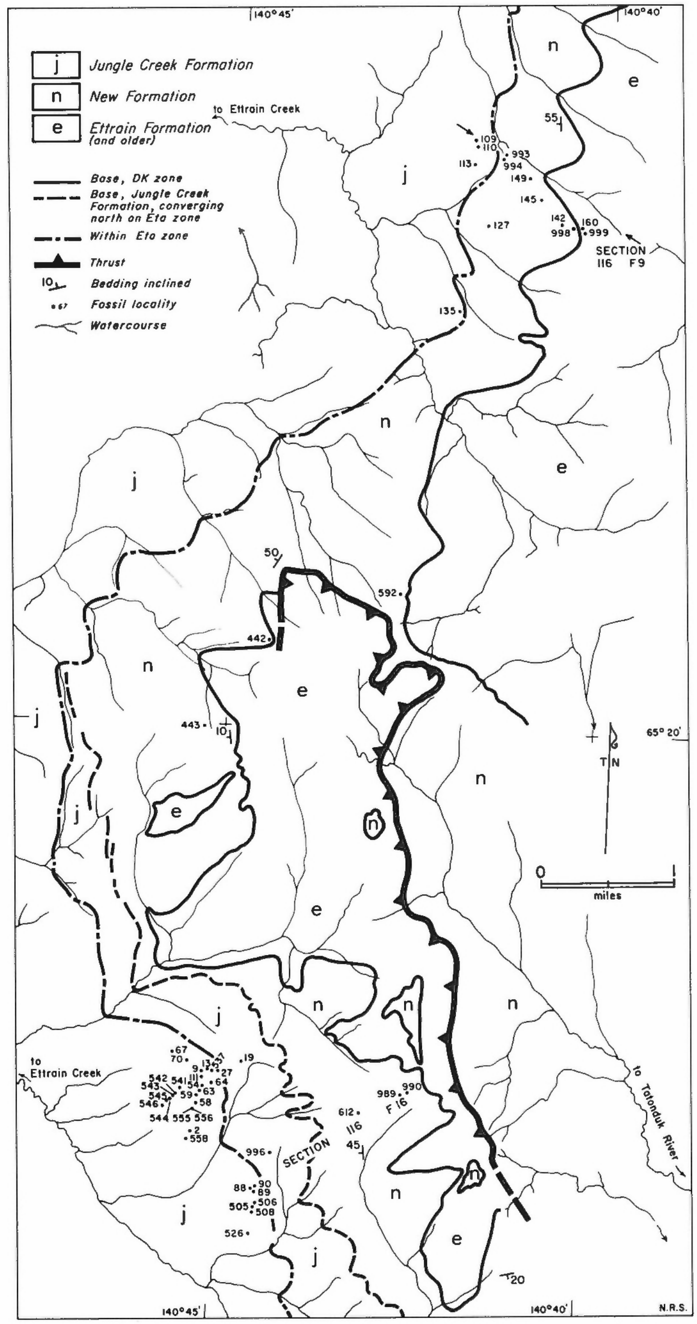

Figure 6. Fossil localities collected by JBW near section 116F-9, type section of the Ettrain Formation (see Bamber and Waterhouse, 1971), near Ettrain Creek, northern Ogilvie Mountains, near 65° 22'N, 140°40'W. (Drawn from airphoto A13138-232, National Air Photo Library, Department of Energy, Mines and Resources.) Lines mark approximate positions within Dk and Eta brachiopod zones, at top of Ettrain Formation (base of Dk zone) and base of Jungle Creek Formation (base of Eta zone).

Figure 7. Fossil localities collected by JBW near section 116F-16 of Bamber and Waterhouse (1971); and Bamber (1972), south of and adjoining Fig. 6. Jungle Creek facies feathers northwards into that of the new formation, shown semidiagramatically, i.e., changing northwards through zones Eka to Eo.

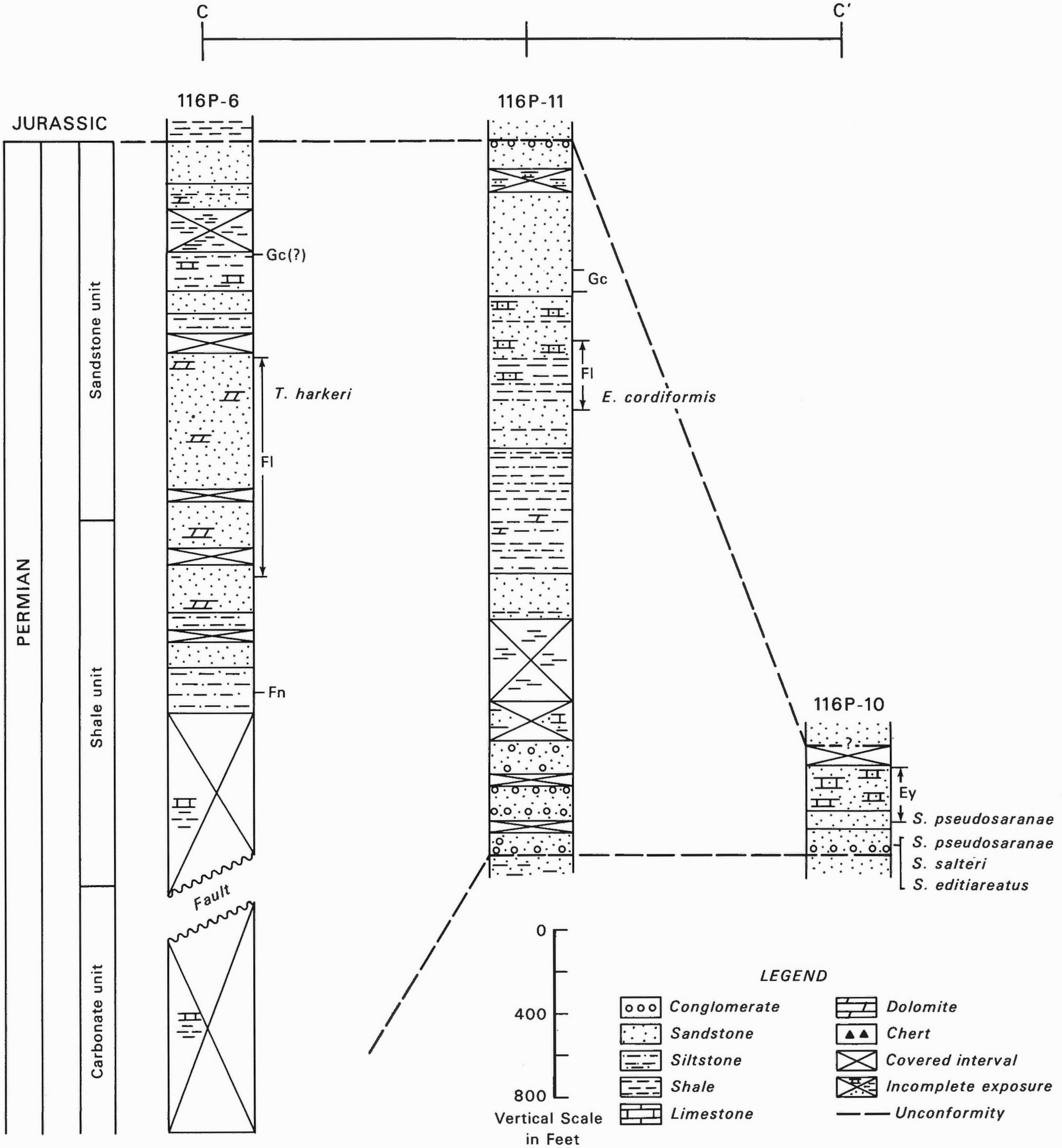

Figure 8. Stratigraphic columns at cross-section C-C¹ (see Fig. 1), northern Richardson Mountains, with location of Spiriferellinae. (After Bamber and Waterhouse, 1971, Fig. 10.)

Table 1. Correlation of brachiopod zones from upper Paleozoic rocks of Yukon Territory

				BRACHIOPOD ZONE		
	STAGE	SUBSTAGE	FORMATION	NORTHERN OGILVIE MTNS-PEEL RIVER AREA	UNIT	NORTHERN RICHARDSON MTNS
PERMIAN	KAZANIAN	Sosnovian	TAHKANDIT FORMATION		Sandstone Unit	
		Kalinovian		*Cancrinelloides* (Gc)		*Cancrinelloides* (Gc)
	KUNGURIAN	"Irenian" Ufimian				
		"Irenian" Elkin				?
		"Irenian" Nevolin		*Thuleproductus* (Ft)		*Lissochonetes* (Fl)
		Filippovian		*Pseudosyrinx* (Fps)		*Neochonetes* (Fn)
	BAIGENDZINIAN	Krasnoufimian		*Sowerbina* (Fs)	Limestone-Shale Unit	
		Sarginian		*Antiquatonia* (Fa)		
	SAKMARIAN	Aktastinian	JUNGLE CREEK FORMATION	*Jakutoproductus* (Ej)		
		Sterlitamakian		*Tornquistia* (Et)		
				Attenuatella (Ea)		
		Tastubian		*Yakovlevia* (Ey)		*Yakovlevia* (Ey)
	ASSELIAN	Kurmaian		*Attenuatella-Tomiopsis* (Eta)		
		Uskalikian		*Orthotichia* (Eo)		
		Surenan		*Kochiproductus-Attenuatella* (Eka)		
CARBONIFEROUS	GSHELIAN	Orenburgian-Gshelian	NEW FORMATION	Unnamed zones -D		
		Kasimovian		*Orthotichia-Septospirifer* (Dos)		
				Kozlowskia (Dk)		
	MOSCOVIAN	Myachkovian	ETTRAIN FM. OR EQUIVALENT	*Gibbospirifer* (Ggb) *Purdonella* (Cpd)		
		Podolian		*Gemmulicosta* (Cg) =*Praehorridonia* (Cp) =*Reticulatia* (Cr)		
		Kashirian		*Buxtonia* (Cb)		
		Vereiian		*Martiniopsis* (Em)		

GSC

Spiriferella pseudotibetana Stepanov is known from the formation on Ellesmere Island. GSC locality C-4081 is said to come from the Belcher Channel Formation of Ellesmere Island, but it appears to contain *Spiriferella keilhavii* (von Buch) and *Timaniella harkeri* Waterhouse, which characterize Kungurian faunas.

Sabine Bay Formation

The Sabine Bay Formation lies between the Belcher Channel and Assistance formations on Sabine Peninsula, Melville Island. It also occurs on Ellesmere Island in a narrow belt from south of Canõn Fiord to Lake Hazen. On Ellesmere Island, the Sabine Bay Formation rests unconformably on the Belcher Channel, or equivalent Tanquary, Formation and is overlain by the Assistance Formation.

Assistance Formation

The Assistance Formation comprises limestone, sandstone and siltstone, in many places poorly consolidated, containing brachiopods of Filippovian age. At its type locality on Grinnell Peninsula, the Assistance overlies the Belcher Channel Formation, and its upper limit forms the present erosional surface. On northeastern Melville Island, it lies unconformably on the Sabine Bay Formation and is overlain by Nassichuk's "Unit A" (1965). The Assistance outcrops discontinuously along the eastern margin of the Sverdrup Basin on Ellesmere Island. *Spiriferella loveni* (Diener) is common in the formation on Devon and Ellesmere islands, and *S. keilhavii* (von Buch) occurs at Ellesmere and Cameron islands. *Alispiriferella gydanensis* (Zavodowsky) is found in the formation on Ellesmere Island and *Timaniella harkeri* Waterhouse on Devon and Ellesmere islands.

Trold Fiord Formation

The Trold Fiord Formation consists mainly of glauconitic sandstone and minor amounts of chert and limestone, up to 300 m thick, with brachiopods of Kazanian (Gc) age. Near Canõn Fiord, the Trold Fiord Formation unconformably overlies the Assistance Formation, and it transgresses south and southeastward to overlie successively Assistance, Sabine Bay, Belcher Channel, Canyon Fiord and lower Paleozoic beds. *Spiriferella loveni* (Diener) and *Alispiriferella gydanensis* (Zavodowsky) are found in this formation on Ellesmere Island.

Van Hauen Formation

The van Hauen Formation outcrops on Raanes Peninsula at Blind Fiord and consists of variably calcareous black siltstone and shale up to 800 m thick. Thorsteinsson (1974) considered it to represent the western equivalent of the Assistance Formation and to grade laterally into that formation. Ammonoids support that correlation (W.W. Nassichuk, pers. com.). A study of *Spiriferella* from the van Hauen Formation suggests that it is partly younger than the Assistance Formation, and partly slightly older and perhaps equivalent to the Trold Fiord Formation. This is supported by other brachiopod studies, which suggest a Nevolin age. The mid-Kungurian *Spiriferella loveni* (Diener) and *S. leviplica* n. sp. are found on Ellesmere Island.

Degerböls Formation

The Degerböls Formation contains up to 350 m of cherty and fossiliferous limestone, which crop out on Ellesmere and northern Axel Heiberg islands. It overlies the van Hauen Formation and probably is equivalent to the Trold Fiord Formation but could also include older beds. *Spiriferella loveni* (Diener) occurs on Ellesmere Island, as does *S. keilhavii* (von Buch) at Great Bear Cape.

Table 2. Summary of upper Paleozoic stratigraphy of the Canadian Arctic Archipelago.

MELVILLE ISLAND		CAMERON I.	DEVON I.	ELLESMERE ISLAND			
NW	NE		Grinnell Peninsula	Bjorne Peninsula	Trold Fiord	Blind Fiord	Cañon Fiord
TRIASSIC				TRIASSIC			
TROLD FIORD FORMATION	*TROLD FIORD FORMATION*	*TROLD FIORD FORMATION*		*DEGERBÖLS FM (168+)*	*TROLD FIORD FM (30)*	*TROLD FIORD FM (30)*	*TROLD FIORD FM(168)*
	UNIT A						
	ASSISTANCE FM (23)		*ASSISTANCE FORMATION (61)*	*ASSISTANCE FORMATION (405)*		*VAN HAUEN FORMATION (683)*	*ASSISTANCE FORMATION (74)*
	SABINE BAY FM (46)						*SABINE BAY FORMATION (194)*
	BELCHER CHANNEL FM(23)		*BELCHER CHANNEL FM (253)*	*BELCHER CHANNEL FORMATION (415)*		*NANSEN FORMATION (1186)*	*TANQUARY FM(664)*
							MOUNT BAYLEY FM(76)
							ANTOINETTE FM (808)
CANYON FIORD FM	*CANYON FIORD FM*			*CANYON FIORD FORMATION (799)*	*CANYON FIORD FORMATION (634)*		
		DEVONIAN	ORDOVICIAN				

Formation thickness (in metres) ....(23)

GSC

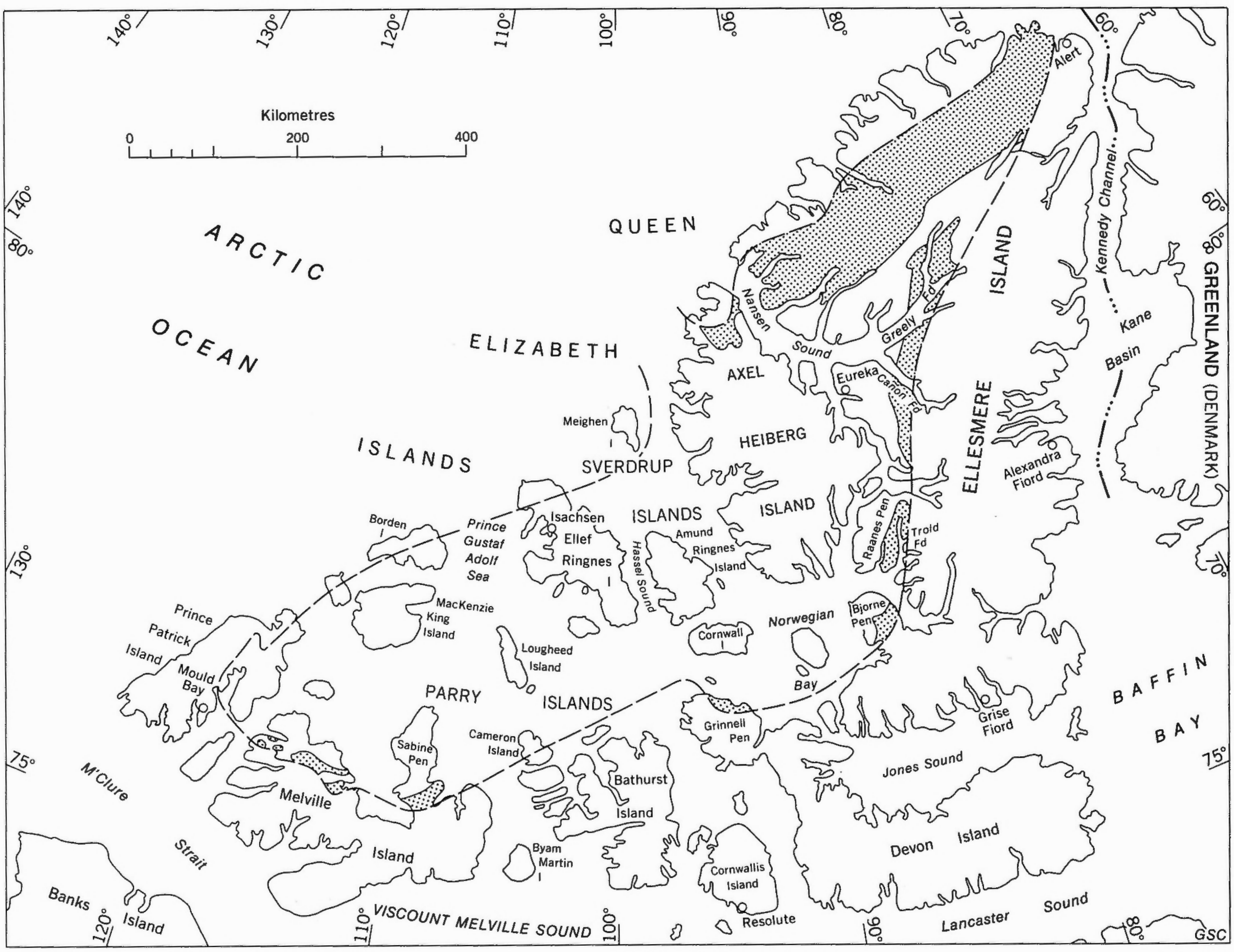

Figure 9. Area of Upper Paleozoic outcrop, Canadian Arctic Archipelago. (shaded area) Upper Paleozoic outcrop. (broken line) Margin of Sverdrup Basin.

MORPHOLOGY AND AUTECOLOGY OF *SPIRIFERELLA* AND ALLIES

Spiriferella is a small- to medium-size spiriferacean with a hinge generally of less than the maximum width. Since the mount of alation is only moderately variable, high alation helps distinguish some species, such as *Spiriferella rajah* (Salter) and *S. supplanta* Waterhouse. The high ventral interarea and low dorsal interarea presumably provided the basis for some sort of ligamental padding that helped open the valves (Sokolskaya, 1941). The ventral umbo is very incurved and massive in some species but small, short and little incurved in others; this is probably a reflection of the life attitude. The delthyrium under the ventral umbo largely is sealed by a convex deltidium with growth lines. A narrow gap may be left for an atrophied pedicle, according to Cooper and Grant (1976, p. 2223). We consider it more likely that this allowed growth of the deltidium and opening of the valves, and thus we infer that the genus probably was not attached by a pedicle, at least not after a juvenile stage. Presumably, *Spiriferella* rested on or partly in the seabed, stabilized by surrounding sediment and its own weight, with the anterior part slanting obliquely upward (Cooper and Grant, 1976, p. 2224).

The sulcus and fold are well developed in *Spiriferella*, and the fold is consistently diagnostic in delimiting species, in terms of its height and costation and especially in the presence or absence of a median groove. It apparently developed along several lines, which sometimes converged morphologically. Presumably, the groove helped to divide the incoming supply of oxygen and food-bearing water and, as a subsidiary function, to guard against intrusion by unwanted particles. The two valves also are plicate and costate, to provide strength to the shell, increase the intake of water and, at the same time, restrict the entrance of undesirable matter (Rudwick, 1970).

The micro-ornament consists of radial capillae and growth increments preserved as concentric lirae with minute pustules across the junction of the two. The pustules appear to have formed on *Spiriferella* during one to four growth increments. Radially, pustules are separated from each other by growth increments that failed to form pustules. Therefore, the spacing appears to have been controlled on a weekly basis, on the assumption that one increment formed each day. Conjecturally, pustules were formed during usually two to four days, perhaps when tides most favourably coincided with temperature to produce optimal feeding conditions, which would recur four times a month. The number of increments per pustule generally is constant in any one fossil locality but varies at different stations over the globe, suggesting that at some regions the pustules formed during a shorter length of time, sometimes only two days. In Australian shells that may be allied to *Elivina* Frederiks, pustules are found on only some shells or parts of shells, and were formed by single increments. The ornament of the type species of *Elivina*, *Spirifer tibetana* Diener is poorly known, but Frederiks found that Urals specimens so identified (incorrectly, in our opinion) lacked pustules, and Cooper and Grant (1976, p. 2241) found that pustules were absent from two or three species in the Guadalupian of the United States. Another phenotypic variation lies in the strength of the growth increments, which are sturdy ridges in *Spiriferella* from the Canadian Arctic Archipelago as compared with the fine laminae in material from the Yukon Territory.

Counts of the growth increments suggest that the shell reached maturity in approximately one year and lived for two to four or five years. However, these counts are based on a few randomly chosen individuals (mainly from the Canadian Arctic) and not on large samples.

Interior

One of the most distinctive features of *Spiriferella* lies in the heavy secondary thickening in the umbonal region of the ventral valve. This substantial secondary calcite helped to weigh the shell down into the sediment, thus helping to compensate for the short hinge and absence of a pedicle. In this respect, *Spiriferella* differs substantially from shells that are of similar shape, such as *Martinia*, *Brachythyris* or *Martiniopsis*. It may be interpreted as a simple and initial tendency by a spiriferacean to replicate the conical shape adopted by several invertebrate phyla, including Rugosa and Scleractinia of the Anthozoa, *Hippurites* of the Bivalvia, and *Richthofenia* of the productid Brachiopoda. But, unlike these shells, *Spiriferella* was not cemented to the substrate. Some Syringothyrididae also developed a subconical habit with very extended ventral umbo and high interarea, but these were not filled with calcite.

The two valves are articulated by means of two ventral teeth held in dorsal sockets as well as small crenulations along the hinge in at least some *Spiriferella* (Waterhouse, 1964, Pl. 28, fig. 4). The teeth are supported by low dental plates, resting in turn on short adminicula (Waterhouse, 1971b) that become buried in secondary shell during ontogenetic development. The muscle field is normal for spiriferaceans, with narrow adductors and wide, deeply striated diductor scars, but it is often cupped or elevated anteriorly above the floor of the valve in *Spiriferella* to retain the base of the muscle insertions at an angle favourable for operating on the dorsal valve. Anteriorly, the muscle field, whether sessile or slightly raised, may be supported by a short sturdy ridge. A myophragm may or may not be present, varying among individuals of one species from one collection. Pustules or pits that acted as bases for the insertion of the goniophores are concentrated on each side of the adminicula and muscle field.

The dorsal valve is thin and is like many other spiriferaceans internally. The cardinal process is vertically laminated and sessile, serving as an attachment for the diductor muscles from the ventral valve, and the adductor scars are subrectangular and faintly impressed. They are subdivided by a very low median septum, or ridge, which may not appear until maturity. The sockets are enclosed by subhorizontal socket plates attached to subvertical crural plates, and these are not supported by tabellae (Waterhouse, 1968). The spire generally is directed posterolaterally, but one specimen of *Spiriferella loveni* (Diener) from the Assistance Formation at Grinnell Peninsula, Devon Island, Canadian Arctic Archipelago, has its spires directed anteriorly (Pl. 5, fig. 8). The specimen may have been a sport, because the spiralia are too delicate to have been disoriented, yet kept intact, after death. Alternatively, they might have been snapped off and repositioned after death. It is not considered that the feature requires taxonomic separation. Pustules and pits show where the goniophores were attached.

Shell structure has not been studied for *Spiriferella*, and whether taleolae are present or absent has not been determined.

Allied genera

In *Elivina* Frederiks 1924, radial capillae apparently did not develop, and pustules are rare. The hinge is typically very short, but this does not appear to be a completely reliable feature. *Eridmatus* Branson 1966 has a moderately wide alate hinge, high fold, deep sulcus, and plicae with narrow interspaces. It is closely related to *Spiriferella*.

Timaniella Barkhatova 1968 differs more. It is characterized mainly by its very transverse outline. This imparted a fairly stable shape with a long hinge, and secondary thickening in the ventral umbonal region is correspondingly reduced.

Alispiriferella n. gen. is distinguished by its subalate hinge and wide sulcus on the dorsal fold. It has substantial thickening in the ventral valve, as *Spiriferella* has, and probably was ancestral to *Timaniella*.

A more distinctive genus is *Plicatospiriferella* n. gen., which has numerous, generally smooth, plicae on both valves.

Abbreviations in the material and localities tables

Area		*Valves*	
Bell	Bell River	j	juvenile
Cam	Cameron Island	i	immature
Dev	Devon Island	em	early maturity
Ett	Ettrain Creek	m	fully mature
Ell	Ellesmere Island	B	both valves
Jun	Jungle Creek		
Peel	Peel River	*Lithology*	
Tat	Tatonduk River	lmst	limestone
Whi	White Mountains	sh	shale
Yuk	Yukon Territory	sls	siltstone
		ss	sandstone

SYSTEMATIC DESCRIPTIONS

Family Licharewiidae Slusareva 1958

Subfamily Spiriferellinae Waterhouse 1968

(junior homonym: Spiriferellidae Termier et al., 1974, p. 136)

The spiriferacean shells *Spiriferella* and its allies generally have been classed with Brachythyrididae Frederiks (Ivanova, in Sarytcheva, 1960; Pitrat, 1965) on the basis of their short hinge and plicae. Waterhouse (1968) referred *Spiriferella* and allies to a new subfamily, Spiriferellinae, and considered that the shortness of the hinge was not significant, as would seem to be confirmed by the great width of the hinge in *Timaniella* Barkhatova. Plicae are, of course, common in many spiriferacean families. To Waterhouse (1968), the familiar relationships were indicated best by the nature of the internal plates and micro-ornament, both of which pointed to a close alliance with the Licharewiinae Slusareva 1958. Nothing has been found to contradict this. The two subfamilies are more closely allied to each other than to the Syringothyridinae Frederiks 1926, which Ivanova (in Sarytcheva, 1960) and Pitrat (1965) associated with Licharewiinae in the family Syringothyrididae. Syringothyridinae often have punctate shells and elaborate apical apparatus in the ventral valve, but they do resemble the Licharewiinae in general appearance and in the dorsal valve. Carter (1974, p. 677) agreed that the Syringothyrididae should be separated from the Licharewiinae.

Termier et al. (1974) proposed the family Spiriferellidae nov., apparently unaware of the earlier proposal by Waterhouse (1968). No indication of interfamilial relationship was provided other than contrasts with the Brachythyrididae. In his review of spiriferid and brachythyridid Brachiopoda, Carter (1974, p. 689) referred the Spiriferellinae Waterhouse to the Spiriferidae, together with Strophopleurinae Carter, Choristitidinae Waterhouse, and Neospiriferinae Waterhouse, but none of the other subfamilies has pustular ornament. Cooper and Grant (1976) offered a most unlikely interpretation for *Spiriferella* and its allies *Eridmatus* and *Elivina*. They placed the three genera within the Brachythyrididae Frederiks and asserted that *Spiriferella* "had descended from *Eridmatus* or one of its relatives in the late Pennsylvanian or Early Permian" (ibid., p. 2220). This is impossible, because species of *Spiriferella* are well known in strata of Middle Carboniferous as well as "late Pennsylvanian", let alone Early Permian age. It is clear that Cooper and Grant based their interpretation almost entirely on the faunal succession within Texas, overlooking the species recorded from the Soviet Union and Canada. Moreover, species of *Spiriferella*, and of the allied form *Plicatospiriferella*, definitely precede occurrences of *Eridmatus*.

Genera within the subfamily

The genera *Spiriferella* Chernyshev, *Eridmatus* Branson, *Timaniella* Barkhatova, *Elivina* Frederiks, *Alispiriferella* n. gen. and *Plicatospiriferella* n. gen. are included in the Spiriferellinae.

Termier et al. (1974, p. 136), in independently erecting the 'new' family Spiriferellidae, included "*Spiriferella* (en général confondu avec *Elivina*), probablement du genre *Eliva* Frederiks, et peut-être aussi de *Tangshanella*." *Tangshanella* Chao, from the Penchi Series of China, is closely costate as in choristitinids, but it is said to have reduced dental plates. No material is available to us for assessment.

Carter (1974, p. 688), in an extensive review of spiriferacean genera, included *Tangshanella* in the Choristitidinae Waterhouse. For the Spiriferellinae Waterhouse he listed the genera *Spiriferella* (presumably incorporating *Elivina*), *Eliva*, *Eridmatus* and *Timaniella*.

The genus *Eliva* Frederiks 1924, based on *Spirifer lyra* Kutorga 1844, is poorly known, but we accept the analysis by Cooper and Grant (1976), which shows it is not a close ally of *Spiriferella*.

Pitrat (1965) included *Blasispirifer* Kulikov 1950 in synonymy of *Spiriferella*. The type species, *Spirifer blasii* de Verneuil, judged from specimens from the Pinega River presented by M.V. Kulikov, VSEGEI, Leningrad, appears to belong to the Neospiriferinae Waterhouse. But Ivanova (in Sarytcheva, 1960, p. 270) referred *Blasispirifer* to *Elivina* Frederiks.

Genus *Spiriferella* Chernyshev 1902

Type species: *Spirifer saranae* de Verneuil 1845

Diagnosis

External. Strongly plicate shells with simple or bundled plicae; maximum width of shell usually in front of hinge; ventral valve with highly convex umbo, interarea typically large, triangular, flat or gently concave, divided by a delthyrium, closed by deltidium; dorsal valve generally less convex and thinner than ventral valve and, therefore, frequently either broken or washed away prior to burial; ventral sulcus distinct, usually costate; crest of dorsal fold rounded or grooved. Micro-ornament formed by network of radial and more prominent concentric capillae with fine pustules.

Internal. Ventral valve with dental and short diverging adminicular plates; umbonal region variably filled with callus, muscle platform sometimes elevated, with anterior low supporting ridge at maturity, tapering anteriorly, tending to overlap outer edges of adminicula; adductors long, narrow; diductors longitudinally striated. Dorsal valve with small, laminated cardinal process, crural plates and subhorizontal socket plates; adductors smooth, rounded. Low septum. Spire usually laterally to posterolaterally directed. Shell impunctate, not known if taleolate.

Spiriferella primaeva n. sp.

Plate 1, figures 1 - 6; Figure 10

Holotype. GSC 35475, JBW locality 227 (Pl. 1, figs. 1, 2, 5)

Paratypes. ROM 28204, 28206, JBW locality 226; GSC 35476, 35477, JBW locality 227

Diagnosis. Small shells with few plicae, low and inconspicuous except for innermost pair. Ventral umbo strongly incurved, dorsal fold with median groove for full length.

Material and localities

Loc.	Area	Brach. zone	Valves: Both	Valves: Ventral	Lithology
(JBW)					
226	Peel	Cp		lem	calc. sls
995	Peel	Cp		lem	calc. sls
999	Ett	Cgb		lem	calc. sls
227	Peel	Cp	1m	1j, 2m	calc. sls
(GSC)					
57070	Tat	Cp		2m	calc. sls

Description

External. Ventral valve well rounded in outline, umbo broad, protruding abruptly beyond hinge at 95-degree angle; cardinal extremities slightly alate, but not prominent; maximum width in front of midlength. Sulcus well formed, at 15-degree angle, bearing median costa as a rule. Fold narrow posteriorly, with narrow median cleft; not known anteriorly. Delthyrium poorly exposed, apparently narrow, has 40-degree angle; presence or absence of deltidial plate not shown.

Inner pair of plicae moderately prominent on both valves; three other pairs faint, and rapidly diminish in strength laterally, with one faint costa or plication near cardinal extremities. Interspaces shallow. Inner two pairs of plicae may bear a subsidiary costa on inner flanks. Dorsal valve has three pairs of narrow plicae and broad interspaces. Micro-ornament on ventral valve ROM 28204 consists of longitudinal capillae, four per mm, and concentric growth lirae, seven in 2 mm, with low pustules, usually aligned along each concentric growth line, rather than alternating as in younger species. Dorsal micro-ornament not known.

Internal. Dental plates short, converging inward at 110 degrees from teeth tracks; adminicula diverge at 95 degrees, largely buried in secondary thickening. Adductors long and narrow, bordered and medianly divided by slender grooves, subdivided posteriorly by low narrow ridge, which persists over posterior wall. Diductors striated longitudinally, broad, tapering anteriorly at 50 degrees.

Dorsal interior not known.

Dimensions

Spec.	Loc.	Width	Length (mm)	Height	Umbonal angle (degrees)
(ROM)	(JBW)				
28204*	226	+28	+25	+15	
28206	226	39	31	18.5	
(GSC)					
35475	227	23.5	+23	11.5	80
35476	227	16	17	8.5	85
35477	227	+20	21.5	9.7	+105
35478	999	21	+19.5	11.5	90

*ROM 28204: Muscle field width 7 mm, length 12 mm, adductor width 2.3 mm

Resemblances. The Yukon specimens are characterized by their massive ventral umbones, costate sulcus and six to eight simple plicae, which are very low laterally and have rare or no costae, and by their fold bearing a shallow median groove. They are close in shape to shells figured as *Spiriferella gjeliensis* Stepanov 1939 by Sarytcheva and Sokolskaya (1952, Pl. 63, fig. 355) from the mid-Carboniferous of the Urals, but the plicae are lower laterally in the Canadian form and the median fold has a groove, which is lacking in the Russian specimens. Other Ural specimens of *gjeliensis*, assigned to *Spiriferella praesaranae* Stepanov by Mironova (1960, Pl. 11, figs. 4-6; 1967, Pl. 4, fig. 5) and to *S. gjeliensis* by Menner et al. (1970, Pl. 11, figs. 3, 4), have more extended, narrower ventral umbones with straight posterior walls, higher lateral plicae, wider sulcus (in the Mironova shells) and subdivided innermost plicae.

The type specimen of *Spiriferella gjeliensis* Stepanov, now assigned to *Plicatospiriferella*, was figured by Nikitin (1890, Pl. 3, fig. 4a,b) from the Gshelian beds at Gshel, near Moscow. It has fairly numerous plicae, five or six pairs on the ventral valve, and a wide sulcus and wide hinge; thus it does not resemble closely the Yukon specimens. Its dorsal fold has a narrow median groove, as in *S. primaeva*.

The late Desmoinesian, Missourian and early Virgilian species *Eridmatus texanus* (Meek) has, as figured by Meek (1876, Pl. 3, fig. 5; Hall and Clarke, 1893, Pl. 37, figs. 16, 17; Dunbar and Condra, 1932, Pl. 38, figs. 6, 7, 8?-10; Cooper, 1944, Pl. 125, figs. 3, 4; and Branson, 1966, Pl. 1, figs. 1-3), a fold like that of *S. primaeva*, and the plicae diminish rapidly to the sides in width and height. It is distinguished from *S. primaeva* by its numerous and costate plicae and wide hinge. *Eridmatus texanus* is especially characteristic of the Missourian of Texas, but it may begin in the late Desmoinesian in Oklahoma. Specimens have been recorded also from the early Virgilian of Texas.

Spiriferella yukonensis n. sp.

Plate 1, figures 11 - 20; Figures 11c-f, 12

1971 *Spiriferella* sp. Bamber and Waterhouse, p. 127, Pl. 11, fig. 7

Holotype. ROM 28205, JBW locality 145 (Pl. 1, figs. 11, 12)

Diagnosis. Moderately convex shells with small ventral umbo; plicae simple, rounded, three to five pairs ventral, four pairs dorsal; sulcus relatively deep and narrow, with three to seven costae; crest of fold cleft for entire length; muscle platform slightly raised.

Material and localities

Loc.	Area	Brach. zone	Valves: Both	Valves: Ventral	Lithology
(JBW)					
142	Ett	D	lem		calc. sls
145	Ett	D	1m	1m	calc. silty fine ss
149	Ett	D		4em, 1m	calc. sls
160	Ett	Dk-?Cgb		1m	ss
442	Ett	Dk		lem	gran. lmst
443	Ett	D		2em	green sls
592	Ett	D		lem	calc. ss and sls
612	Ett	D		lem	silty skel. carb.
802	Ett	D		lem	silty carb.
989	Ett	D		1m	gran. carb.
990	Ett	D		1m	calc. sls
998	Ett	Dk		lem	calc. sls
(GSC)					
57142	Ett	D		lem, 2m	silty lmst
57143	Tat	Dos		9em, 1m	silty sh
57155	Tat	Dos		4em, 7m	silty sh

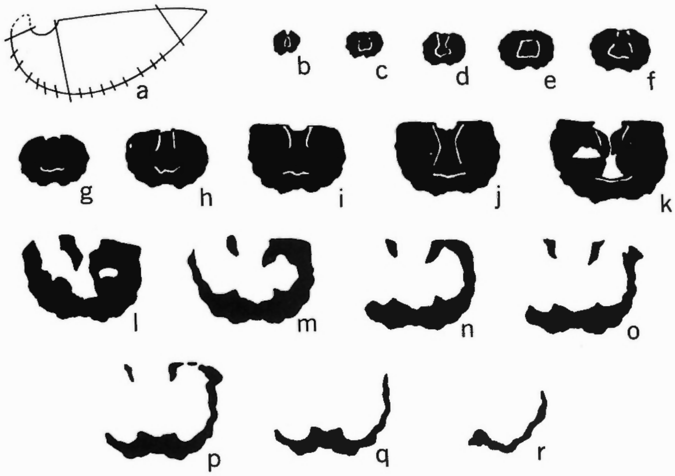

Figure 10. Spiriferella primaeva *n. sp., serial sections, ROM 28206, JBW loc. 226, Ettrain equivalents, Peel River. Sequence from umbo to anterior margin. Approx. x75. Figure in top left shows position of sections.*

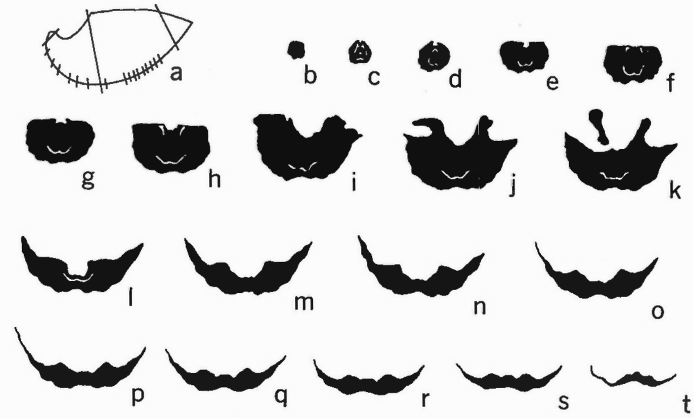

Figure 12. Spiriferella yukonensis *n. sp., serial sections, GSC 30741, GSC loc. 57155, Jungle Creek Formation, Tatonduk River. Sequence from umbo to anterior margin. Approx. x75.*

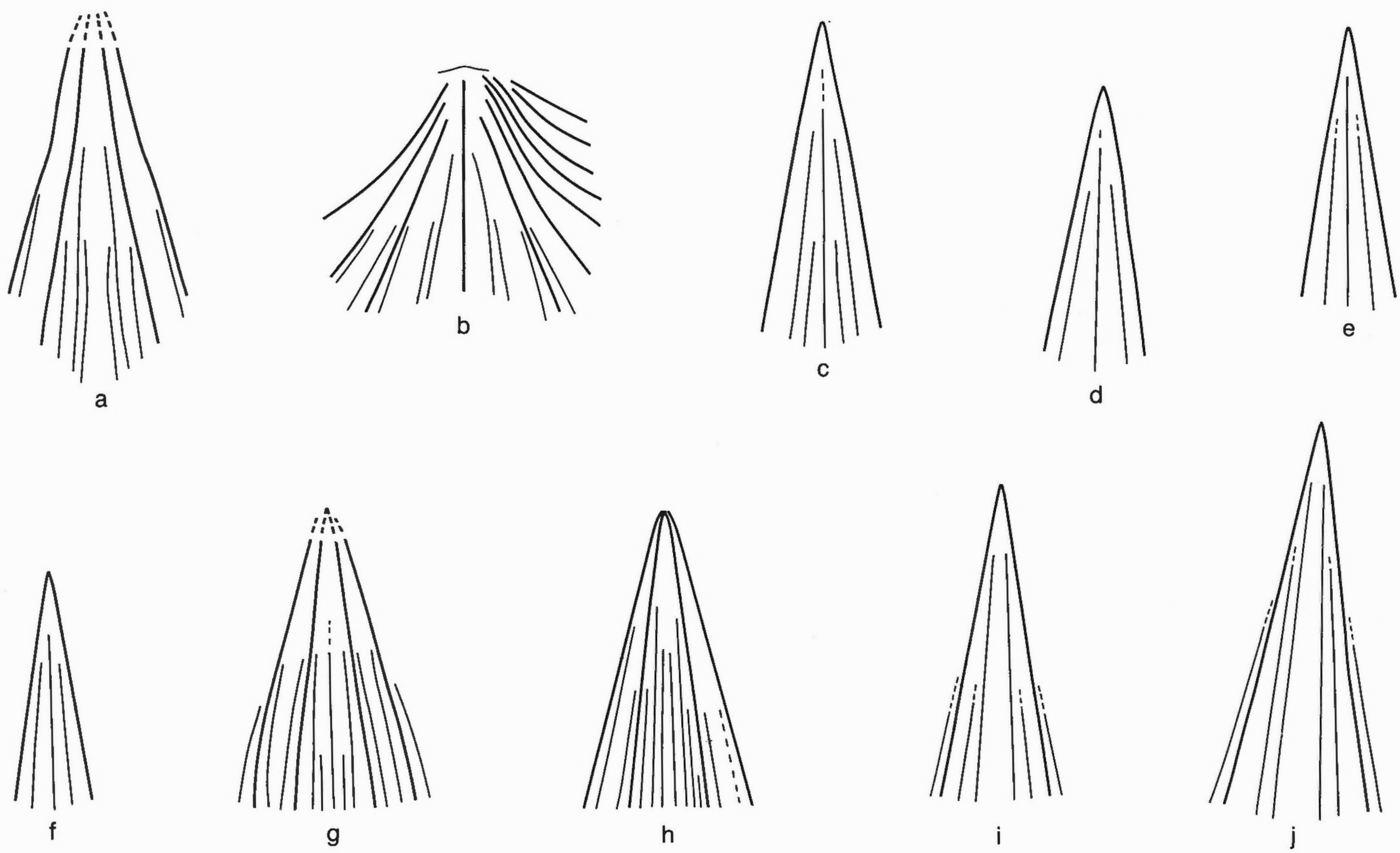

Figure 11. Costal diagrams. Plicatospiriferella canadensis *n. sp.: (a, b) GSC 26855, GSC loc. 53726, Ettrain equivalent, Peel River, ventral and dorsal valves.* Spiriferella yukonensis *n. sp.: (c) ROM 28207, JBW loc. 145, new formation, Ettrain Creek area; (d) GSC 30742, GSC loc. 57155, Jungle Creek Formation Tatonduk River; (e) Rom 28205, JBW loc. 145, new formation, Ettrain Creek area; (f) GSC 30743, GSC loc. 57155, Jungle Creek Formation, Tatonduk River.* Eridmatus petita *n. sp.: (g) GSC 35501, JBW loc. 19, Jungle Creek Formation, Ettrain Creek area; (h) GSC 35502 (holotype), same locality.* Alispiriferella ordinaria *Einor: (i) GSC 30755, GSC loc. 55137 Jungle Creek Formation, Ogilvie Mountains (j) GSC 30752, same locality. All ventral valves unless stated otherwise. Approx. x1.*

Description

External. Moderately convex shells, longer than they are wide, maximum width at or near hinge; dorsal valve about 0.8 as long as ventral valve; ventral umbo small, strongly incurved; umbonal angle 70 to 80 degrees; ventral interarea highly concave. Delthyrial angle 75 degrees in GSC 30746 from GSC locality 57155 (Tatonduk River). Sulcus starts at umbo, narrow, moderately deep, bearing median costa that starts between 5 and 10 mm from umbo; sulcal angle 18 to 20 degrees. Fold well formed, distinct; crest has very shallow median groove for entire length. Ventral valve has three to five (usually four) pairs of rounded plicae; dorsal valve has four pairs of plicae; innermost pair on each valve develops a broad low costa on either side at the anterior third; outer plicae also may show traces of one or rarely two low costae. A large specimen, GSC 30743 from GSC locality 57143 (Tatonduk River), is more costate anteriorly, with two or three costae on plicae.

Internal. Judged from one sectioned and two other prepared specimens, short, dental plates converge from teeth at 95 degrees in GSC 30746 from GSC locality 57155 (Tatonduk River); adminicula almost or completely buried in secondary thickening. Muscle field broad, tapering anteriorly at 45 degrees, on slightly raised platform; adductors depressed, 1.0 mm wide posteriorly (measured together), 1.5 mm wide anteriorly, divided by low median groove; diductors striated longitudinally, two grooves per mm over anterior third. Posterior face behind muscle field marked by shallow groove. In immature specimen GSC 35473 from GSC locality 57155 (Tatonduk River), the adductors are wide and subdivided posteriorly by a narrow myophragm. Adminicula diverge to the floor of the valve at 60 degrees.

Dimensions (ventral valves)

Spec.	Loc.	Width	Length	Height	Hinge width	Umbonal angle
		(mm)				(degrees)
(ROM)	(JBW)					
28219	442	25.1	25.8	17.5B	18.3	90
(GSC)						
35480	443	+18	+14.5	7	+15	70
35482	802	+25	+19	11	+25	80
35483	612	31	22	11.5	31	
35484	997	25	21.5	+10	25	93
35485	997	+17.5	15.5	+8	?	115
35474	998	+17.5	16.8	7.5		75
(ROM)						
28205	145	+28	31.5	12.3	28	90
28207	145	+32	+29	+16		93
(GSC)	(GSC)					
30743	57143	+30	28	16	+30	
35486	57143	+21.5	18	10	17.5	68
35487	57143	+23	+23	11	20	80
30742	57155	+21	+24	+11.5		85
30744	57155	+29	+25	+14		85
35488	57155	13	14.5	6	11.5	75
35489	57155	16	15	7	13	70
35490	57155	+17.5	+16	+10.5	+16.5	80
35491	57155	+18.5	19	10.5	15	70
35492	57155	+18.5	+16.5	7.5	?13	80
35493	57155	20.5	21	9	15.5	93
35494	57155	+23	+21.5	12	19.8	85
35495	57155	20.5	20.8	13	15.5	78
35722	57142	+37	+39	+20	?32	100
35723	57142	+37	+40	+17.5	?32	120

Variation. Specimens from JBW locality 145 in the *Kozlowskia* Zone (Dk) of the Ettrain Creek area are larger than shells from the Tatonduk River (Dos Zone, GSC locs. 57155, 57143) and have broader interspaces between plicae, slightly wider sulcus, and slightly less incurved ventral umbo. They have similar sulcal costae and divided fold. Shell GSC 35474 from JBW locality 998 (Ettrain Creek) has high plicae with deep interspaces and sulcus, like those of two valves from JBW locality 443 (Ettrain Creek). Other specimens, all from the same Ettrain Creek area, vary in the number of sulcal costae: most have three (JBW loc. 612), others have two (JBW locs. 443, 802), some have one (JBW loc. 442). Two large ventral valves (GSC loc. 57143; Jungle Creek) have massive umbones and costate plicae, and a third ventral valve is narrower than usual.

Resemblances. *Plicatospiriferella gjeliensis* (Stepanov, 1939) from the Bashkirian Urals and Yukon Territory has a narrow sulcus with few costae, but it differs from *S. yukonensis* in having more pairs of narrow plicae. The new species is moderately close to *Spiriferella primaeva* n. sp. in shape and umbo, but its plicae are better defined and narrower, with wider interspaces.

Spiriferella yukonensis differs from the Sakmarian species *Spiriferella salteri* (Chernyshev) of the Urals and Timan in its narrower sulcus and less steeply rounded lateral slopes.

Spiriferella pseudodraschei Einor 1939

Plate 2, figures 14 - 19; Plate 3, figures 1 - 13;
Figure 13

?1935 *Spiriferella draschei* not Toula, Miloradovich, p. 129, Pl. 4, figs. 9, 10, Textfig. 21

1939 *Spirifer (Spiriferella) keilhavii* var. *pseudodraschei* Einor, in Likharev and Einor, p. 218, Pl. 24, figs. 6 - 9

1939 *Spirifer (Spiriferella) saranae* var. *wimani* not Grabau, Einor, in Likharev and Einor, p. 138, 217, Pl. 22, fig. 7, Pl. 23, figs. 2 - 5

1957 *Spiriferella draschei* (not Toula), Cooper, p. 56, Pl. 11C, figs. 7 - 18

?1957 *Spiriferella parva* Cooper, p. 57, Pl. 11A, figs. 1 - 5

Holotype (by original designation). Specimen figured by Likharev and Einor (1939, Pl. 24, fig. 9a, b); kept at Chernyshev Museum, Leningrad

Diagnosis. Small, rounded to elongate shells, narrow sulcus and fold; sulcus with two to five costae; ventral plicae broad, rounded, generally paucicostate, innermost pair often subdivided in two by prominent intersulcal costa; dorsal plicae sharply defined; fold high, narrow, with slender groove arising a few millimetres in front of umbo; muscle platform is relatively small, narrow, has raised borders, and is prolonged anteriorly by ridge; adductors broad; secondary thickening covers posterior walls thickly at maturity, and muscle field lies well forward.

Material and localities

Loc.	Area	Brach. zone	Valves: Both	Ventral	Dorsal	Lithology
(JBW)						
2	Ett	Ej	1m	5j, 1em, 1m		fine ss
13	Ett	Ey		1em		sls
54	Ett	Ey		1j, 2i, 3em, 2m	1j	calc. sls
58	Ett	Ey	1i, 2m	3m	1i	med. ss
59	Ett	Ey		1i, 1m		plant ms
63	Ett	Ey	1m	1j, 1i		fine ss
64	Ett	Ey		1j; 8em, 4m		med fine ss
70	Ett	E		1m		silty ss

88	Ett	Ey		15j, 102i, 4m	20i, 2m	fine ss
89	Ett	Ey	1i, 4em	14i, 6em	2i	fine ss
90	Ett	Ey		6em		fine calc ss
109	Ett	Ey		2i, 1m	1m	sandy ss
110	Ett	Ey		1j, 12em, 3m		calc. ss
505	Ett	Ey	1m	1j, 4i, 1m		sls
506	Ett	Ey	1j	2j, 19i, 20em, 8m		silty ss
526	Ett	Ej		1em		sandy sls
537	Ett	Ej		1j; 1em, 2m		calc fine sls
541	Ett	Ey		1j		sandy sls
542	Ett	Et		1i	1i	sandy sls
543	Ett	Et	1m	1em	1m	silty fine ss
545	Ett	Ej	3em	1j; 10i, 7m	1em	silty ss
546	Ett	Ej		2i,6m		silty fine ss
554	Ett	Ey?	1m	2m		silty fine ss
555	Ett	?Ey	1em	4j, 11em, 5m		sandy sls
556 (GSC)	Ett	E		4em		sandy lmst
53813	Peel	Ey		1j, 2i		
53814	Peel	Ey		1em		sandy sls
53818	Peel	Ej-Et		2i, 5m	1i, 2m	sandy sls
54000	Jun	Ea	1m	5i, 1m		sls
54011	Bell	Ey	1m	13j, 8i, 8m	1i	ss

Description

External. Small to medium-small convex shells, equidimensional or slightly transverse to elongate; ventral umbo small, incurved, but covering little of the delthyrium, posterior walls steep and generally low, imparting hunched appearance, concave to convex posteriorly in outline; cardinal extremities rounded at 110 to 150 degrees. Interarea wide, and high in ventral valve, not strongly incurved, delthyrial angle narrow, 40 to 50 degrees, deltidial plate not preserved. Sulcus narrow, generally has two to five costae between crests of innermost plicae, median costa usually present. Sulcal angle 17 to 20 degrees, flaring anteriorly. Dorsal fold low but distinct, crest divided some 2 to 4 mm in front of dorsal beak by narrow shallow groove; flanks of fold have single sharply defined costa that may trifurcate over anterior third of shell length.

Ventral valve has five pairs of broad rounded plicae separated by shallow interspaces. Inner pair and occasionally adjoining pair tend to bifurcate anteriorly into subplicae. All but the most distal pair have one adsulcal costa about one third as wide as the plication and a minor absulcal costa in the anterior half. Dorsal valve has four pairs of sharply defined plicae; first pair subdivides into three, others into two over anterior third of shell length. Micro-ornament of radial lirae, eight to ten per mm anteriorly, and eight to twelve concentric lirae per mm. Pustules develop at intersections in dorsal valve and alternate on ventral valve.

Internal. Dental plates converge inward at 50 to 60 degrees and up to 90 degrees from teeth, supported by short adminicula, which diverge narrowly to floor and diverge forward at 90 degrees, buried in secondary thickening at full maturity. A small forked plate with median ridge lies between adminicula in immature shells; it leaves low ridges in larger specimens. Muscle platform narrow, divided by groove in some specimens, slightly raised, with anterior sides converging at 25 to 30 degrees, raised as ridges, and prolonged anteriorly as median ridge. Adductors wide, especially in juvenile and immature shells, separated by weak myophragm in some specimens, especially mature ones. Diductors weakly striated longitudinally, not extending as far forward as adductors. Interior surface of valve dotted with tiny, irregular pits pointing forward.

Dorsal interior known from specimens from JBW locality 88. Cardinal process small, has 16 vertical laminae, dental sockets small, socket plates subhorizontal, crural plates low. Median septum arises some distance in front of base of cardinal process but fails to reach midlength.

Variation. Specimens vary in costation and to some extent in other details. Most come from the *Yakovlevia* Zone. Shells from the Ettrain Creek area at JBW localities 13, 63 and 58 are typical. Amongst other specimens from the Ettrain Creek area, the two specimens from JBW locality 59 are noncostate, with the ventral umbo slightly higher than usual. Ventral valves from JBW locality 64 are not well preserved but appear to have the broad short umbo and the muscle field typical of the species, with a median costal rib. Specimens from JBW locality 505 are typical, and they are moderately costate; those from JBW locality 506 are transverse, some smooth, others (larger shells) costate. Specimens from JBW locality 109 have the typical hunched shape; most have few or no costae. Shells from JBW locality 554 have few costae and are typical. Shells from JBW locality 556 are not well preserved; the dorsal groove possibly commences in front of the dorsal beak, and the umbo is obscure but probably typical. Specimens from JBW locality 555 include one massive mature ventral valve, GSC 35562, that looks somewhat like *Spiriferella saranae* (de Verneuil), as discussed below, in its massive shoulders and shape, but the umbo and hinge are destroyed and the appearance may be misleading. It is accompanied by typical specimens of the species here described, but found in a siltier, less calcareous matrix. Possibly the shells were collected from two layers (exposures are not good at the particular locality), but whether these are really two species is not certain.

Specimens from GSC locality 54011, Bell River, Richardson Mountains, are variable; some have smooth plicae, others have dense costae. The position of maximum width varies from midlength to the anterior third. In most specimens the umbo and other details are typical of the species, but one ventral valve (and possibly a second, less well preserved, specimen) is closer to *Spiriferella saranae* (de Verneuil). Immature specimens from the Peel River area at GSC locality 53814 (Ey) are typical, but a mature, less well preserved specimen cannot be identified with certainty.

Specimens from the ?*Jakutoproductus* Zone (Ej) in the Peel River area at GSC locality 53818 have wide hinges and very low ventral umbones. The plicae are high and closely costate.

Other specimens from GSC locality 54000 (Ea) from the Jungle Creek area, are strongly incurved and have two adsulcal costae anteriorly over the two pairs of high narrow plicae next to the innermost pair.

Resemblances. The shells are characterized by their broad short umbo, which is not strongly incurved over the hinge, unlike *Eridmatus petita*. The inner plicae tend to subdivide and the fold generally lacks a groove posteriorly.

The Canadian shells apparently are identical with *Spirifer (Spiriferella) keilhavii pseudodraschei* Einor (not *pseudosaranae* as in caption in Likharev and Einor, 1939, Pl. 24, figs. 6-9) from Lower Permian beds of Novaya Zemlya. It has a somewhat similar shape, but with small, broader ventral umbo and more concave posterior walls, and narrow, straight, higher plicae without costae. The dorsal valve has a high umbo and slight median groove, if any.

Early Permian specimens from the west coast of Cape Loushkin, Novaya Zemlya, identified as *Spirifer (Spiriferella) saranae wimani* Grabau by Einor (in Likharev and Einor, 1939, p. 138, Pl. 22, fig. 7, Pl. 23, figs. 2-5), possibly are related, having similar shape and ornament, including the subdivided inner plication. The dorsal valve has a shallow interior groove. The Mongolian specimens, named *Spiriferella salteri wimani* Grabau (1931, p. 138, Pl. 19,

Spec.	Loc.	Width	Length	Dorsal length	Height	Muscle width	Field length	Hinge width	Umbonal angle
					(mm)				(degrees)
(GSC)	(JBW)								
35516	88	27.5		22	7			20	
35517	88	19.5	16.5		4.8			14	120
35518	88	18.5	16.5		5.8	3.3	4.2	15.5	115
35519	88	26.2	23.4		10.2	5	11	16	?120
35520	88	20.3	15		?3.5	4.5	6.5	15	?110
35521	88	16.5		14	3			11.5	
35522	88	18		13	3.5			12	
35523	89	16.1	15	13.5	9.5B	?3		10.5	100
35524*	89	20.7	+18.5	15.5	13.3B	4.5	7	13.5	
35525*	89	25.2	25.2	20.7	17.5	4.3	11.2	18.7	
35526	89	25		17.5	6.6			18.5	
35528	89	16.5	21		7.3	4.8	9.2	12	105
35529	89	20.5		19.5	4.8			16.5	
35530	89	27.3	27.3		?9	5.3	15	19	
(ROM)									
28209	89	+16	+16.5		?3.5	4.6	9.4	?11.5	
28211	89	+18	+15		?6	4.8	6.8	?13	
28212	89	20.5	19.8		7.5			?12.5	105
28217	89	21.3		17.9	5.2			16.5	
28221	89	22.5	?17		8	4.1	7.2		
(GSC)									
35531	88	15		?11.5	3.4			11.7	
35532	88	19		13.6	6			13.9	
35533	88	16	16.3		6.3	3.8		11.7	
35534	88	20		+13.5	3.1			16.5	
35536*	58	19	?21.5	17.5	11.5B	4	+7.5	14	
35537*	58	24	27.5	21.5	20.5B	5.5	?11.5	12.3	
35538	58	17.6		12.3	3.6			14.8	
35539	59	19	22.5		9.3			23.4	100
35540	63	14.8	+12.5		?3	3.5	7	?10	
35541	70	31.5	29.5		13			19.5	100
35542	505	21.8	15		?7	4.5	9	?12	
35543	505	21.5	+15		?6	3.5	6	8.5	
35544*	505	34.5	23.5	19	22.5	6	?14	22	
35545	505	20	18.5		9			13.5	110
35568g	505	17.3	14.5		5.8			?13.5	100
35546	506	18	14.7		6.4			?12.5	120
35547g	506	13	14		6.5			?11	120
35548	506	+17.5	19		8.5			15	80
35549	506	?25	22.5		9			?13	105
35550	506	17	16		7			11	95
35551g	506	20	17		6			14.5	100
35553*	543	23.5	22.7	21	13.2B	5.5	12.5	16.5	
35554	543	?19	15.5		6.2			?11	?105
35555	545	21		17	6.5			13.5	
35556	545	25.5		19.5	7			19.5	
35557*	545	23.5	21	18	16.5B	5	9	15	
35558	545	23	24		12			?15	110
35559	545	28	29.5		13.5				
35560*	554	25.5	25.5	21	11	4.7	?7	17	
35563	555	22	16		6.5			5	105
35561	555	18	18		8				?100
35564g	555	17	13		6			11	105
35565	555	21	19.5		6.5	3.5	8.3	?10.5	
35566	555	34.3	+27		+19.5			28.5	
35567	555	20.5	18		9.3			17.5	102
35569g	109	18	12.5		3.5				
35570	2	15.3	13		5.5			12	100
35571	2	32	37	34.5				24.5	105
	(GSC)								
35572	53814	23	21		7			19	100
35573	54011	18		10.5	3.2			16.4	
35574	54011	+12.5	11.5		6			10.8	110
35575	54011	+18	15.4		6.2			?15.5	115
35576	54011	21	20.5		9			16	100
35577	54011	14	11		5.5			?12	110
35578	54011	+31.5	31		17.5			23.8	110
26949	54011	+35	31		15.5			25	130
30758	54011	39.5	36.5	31	25.3B			25.4	
35603	54000	13	+11.5		6			10.3	75

* Internal moulds. g Measured from growth line.

figs. 2a - c, 3a - c, 5b, Pl. 20, fig. 8, Pl. 22, fig. 9, Pl. 23, fig. 3), generally have a more extended ventral umbo.

Shells figured as *Spiriferella salteri polaris* ?not Wiman by Einor (1939, Pl. 22, figs. 2, 3) from Cape Loushkin possibly are similar, but no dorsal valve is known. The holotype of *S. saranae pseudosaranae* Einor (in Likharev and Einor, 1939, Pl. 22, fig. 6, Pl. 23, fig. 1) is narrower than the Canadian shells and its umbo may be slightly more incurved, but it could be a variant of the others. As *S. pseudodraschei* is represented by better material, including dorsal valves, this name is preferable.

Oregon shells assigned by Cooper (1957) to *Spiriferella draschei* (Toula) appear to be conspecific in known details, though the interior is not described. Cooper erroneously dated the specimens as Wordian, but the actual age is Asselian and Sakmarian, as shown by Bamber and Waterhouse (1971). One specimen from a locality with so-called *S. draschei* was named *Spiriferella parva* Cooper (1957, Pl. 11A, figs. 1 - 5). It is similar in many details but was distinguished by Cooper on the basis of its long subparallel sides. The fold appears to be high and narrow, and the umbo is more incurved in *S. parva*. None of these differences appears to be significant. *Spiriferella talbeica* Ifanova (in Ifanova and Semenova, 1972, p. 140, Pl. 13, figs. 3, 4) from Kungurian beds of Petchora is similar in general appearance (size, shape, and ornament), but it is not well known internally. Its ventral umbo is incurved slightly more, the hinge is narrower, and the lateral plicae are lower. The similar *Spiriferella* sp. of Grunt and Dimetriev (1973, Pl. 9, fig. 9) from the Darvasian Stage of the Pamirs could prove to be allied. A shell from the Lower Permian Buttle Lake Group of Vancouver Island identified by Yole (1963, Pl. 1, figs. 6, 7) as *Spiriferella saranae* (de Verneuil) might be allied or identical.

The Yukon material appears to closely resemble *Spirifer waageni* Chernyshev (1889, Pl. 2, fig. 2a - c), described from Artinskian beds of Bijas River in the Urals. The main distinction lies in the dorsal fold of *S. waageni*, which is less costate and has only a faint but distinct groove. The ventral umbo is short and not extended.

The Yukon material is somewhat similar to *Spiriferella salteri* Chernyshev (1902, p. 528, Pl. 12, figs. 5, 6), described from Artinskian beds (Sarwa River) and *Schwagerina* beds (Indiga River) of the Urals and from mid-Sakmarian Ilibei beds of Timan (Barkhatova, 1970, Pl. 19, figs. 6, 7, 9 - 14). The shape is similar but not identical; the Russian form has a massive, broad ventral umbo somewhat more incurved over the delthyrium, and a wide alate hinge. Plicae are raised and less rounded. The posterior walls of the Russian shells do not appear to diverge quite as widely as they do in the Yukon material, and ears are better distinguished.

The species somewhat resembles *Spirifer interplicatus baschkirica* Chernyshev (1902, Pl. 6, figs. 1 - 4) from the *Schwagerina* Limestone of Timan, characterized by its small umbo and rounded outline, but the hinge is wider in the Russian form and the cardinal extremities alate. A specimen from the Carnian Alps, figured by Heritsch (1935, Pl. 2, fig. 33), looks similar to Chernyshev's types.

Spiriferella saranae (de Verneuil 1845)

Plate 4, figures 1 - 11; Figures 14, 16a, c

1845 *Spirifer saranae* de Verneuil, p. 169, Pl. 6, fig. 15a,b
1846 *Spirifer saranae* de Verneuil, in Keyserling, Pl. 8, figs. 4, 5
1860 *Spirifer saranae* de Verneuil, Grünewaldt, p. 98, Pl. 4, fig. 3a - c
1889 *Spiriferella saranae* de Verneuil, Chernyshev, p. 368, Pl. 7, fig. 25a - c
1939 *Spirifer (Spiriferella) saranae* (de Verneuil), Einor, in Likharev and Einor, p. 133, Pl. 22, fig. 1
1960 *Spiriferella saranae* (not de Verneuil), Ivanova, in Sarytcheva, p. 270, Pl. 60, figs. 1, 2
?1970 *Spiriferella kolymaensis* Zavodowsky, p. 162, Pl. 36, figs. 3, 4, Pl. 38, figs. 4 - 6, Pl. 39, fig. 1
1971 *Spiriferella* aff. *saranae* (de Verneuil), Bamber and Waterhouse, Pl. 14, fig. 7
1971 *Spiriferella* cf. *saranae* (de Verneuil), Bamber and Waterhouse, Pl. 14, figs. 9, 13
1971 *Spiriferella* sp. Bamber and Waterhouse, Pl. 14, fig. 12
1971 *Spiriferella saranae* (de Verneuil), Bamber and Waterhouse, p. 156
1971 *Spiriferella editiareatus* not Einor, Bamber and Waterhouse, p. 154, Pl. 14, fig. 8

Lectotype. Specimen figured by de Verneuil (1845, p. 169, Pl. 6, fig. 15a, b) from the Artinskian horizon, Sarana River, south of Krasnoufimsk, Ural Mountains, USSR

Diagnosis. Shells of medium size, elongate at maturity, with highly inflated and well incurved ventral umbo, angle 80 to 100 degrees, and massive high posterior walls, concave or straight in outline. Sulcus weakly costate, often with well defined borders and one or two median costae variably defined, fold sharply or weakly costate. Ventral muscle field generally short, having low bordering ridges and anterior ridge.

Material and localities

Loc.	Area	Brach. zone	Valves: Both	Ventral	Dorsal	Lithology
(JBW)						
9	Ett	Ey		1m		fine sls
67	Ett	E		1i (indet.)		sls
111	Ett	Ey	1m	1j, 10i, 10m	1i, 1m ? 1em	fine ss
113	Ett	Ey		1j, 1i, 2m		fine ss
232	Peel	Ey		3em	1em	sls
508	Ett	Ey		4em		fine ss
558	Ett	Ej		1i, 10m	1em	sandy sls
(GSC)						
C-4054	Ell	Ej	1i			?calc. sls
C-4229	Yuk	Ej	1m	1		sls
C-4230	Yuk	?Ej	1m	1j, 1em, 2m		sls
53259	Jun	E		1em		sls
53703	Peel	Ey		1em		sls
53705	Peel	Ey	1i	3j, 7i		sls
53706	Peel	Ey		1m		grit
53707	Peel	Ey		1em		sls
53709	Peel	Ej	1i, 1m	11em, 1m		sls
53710	Peel	Ey	2em	2i, 9em, 1m		sls
53712	Peel	Ey	1m	1em, 1m		sls
53713	Peel	Ey	2em, 1m	1i, 7em, 1m		sls
53715	Peel	Ey		1m		sandy sls
53720	Peel	Ey	1i, 1em	1j, 7i		sls
53722	Peel	Ey	1em	1j, 4i, 5em, 1m		calc. sls
53856	Bell	Ey		3em, 3m	1i, 1em	calc. sls
53860	Bell		1m			sls
54011	Bell	E		1j		ss
56917	Tat	Ej		1i		sls
56972	Ett	E		2m		sls
56977	Ett	Ey		1i, 5m		calc. sls
56999	Ett	Ey		2em, 3m		sls carb.
57141	Ett	Ej		65m		calc. sls

Description

External. Shells moderately convex, elongate at maturity, maximum width at about midlength; lateral flanks slope at 60 to 70 degrees to commissure near hinge; ventral umbo highly inflated, massive, prominent, extends beyond hinge for 0.25 of shell length, tip blunt, angle generally close to 90 degrees. Ventral interarea length/width ratio 0.34, usually strongly concave under beak, cardinal extremities obtuse to bluntly angular. Tiny forked convex plate lies at top of open delthyrium in GSC 30769, from GSC locality 53707, Peel River, like double deltidium. Dorsal valve elongate, subrectangular. Sulcus fairly shallow, gently to acutely V-shaped in cross-section, produced anteriorly to a pointed tongue; sulcal angle close to 19 degrees, may flare

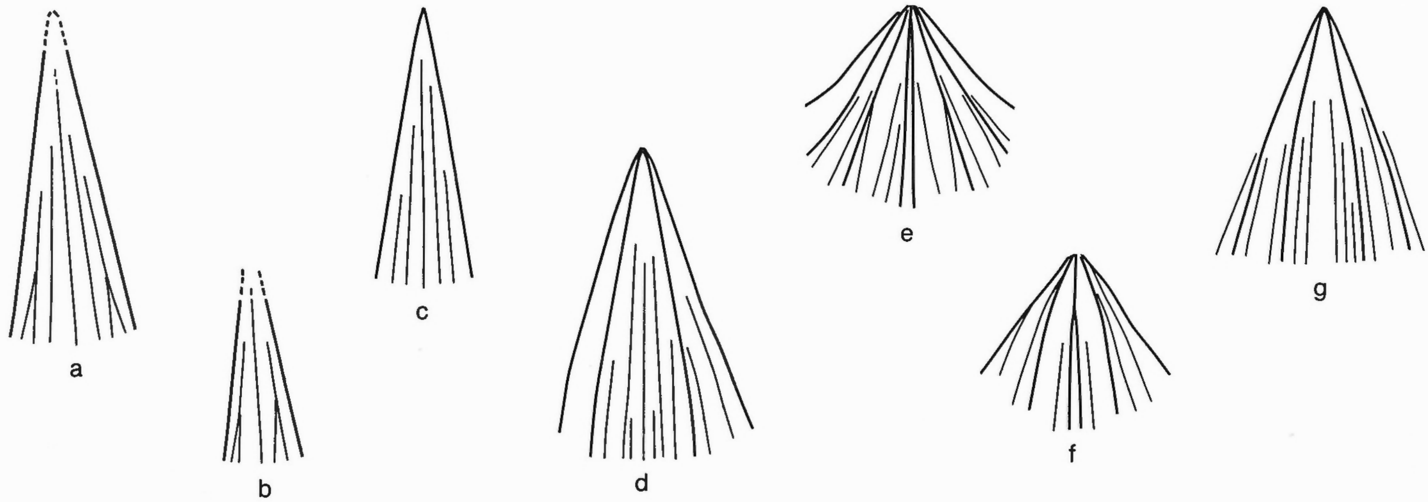

Figure 13. Costal diagrams. Spiriferella pseudodraschei *Einor, from Jungle Creek Formation: (a) GSC 30759, GSC loc. 53818, Peel River; (b) ROM 28220, JBW loc. 64, Ettrain Creek area; (c) GSC 30761, GSC loc. 53713 Peel River; (d) GSC 35568, JBW loc. 505, Ettrain Creek area; (e) GSC 35529, JBW loc. 89 (dorsal), Ettrain Creek area; (f) GSC 35521, JBW loc 88 (dorsal), Ettrain Creek area; (g) GSC 35567, JBW loc. 555, Ettrain Creek area. All ventral valves unless stated otherwise. Approx. x1.*

outward anteriorly. Sulcus has six to eight week costae; median costa, if present, does not bifurcate, but it is replaced by two costae for entire length in some individuals. Fold prominent and high, crest narrow with a slender groove running at its full length, flanks of fold steep, diverging at 35 degrees from umbo; each flank has a single costa, which bifurcates at midlength, and there is another lateral costa anteriorly, where fold flares outward (GSC 35607, from GSC loc. 53705, Peel River area).

Ventral value has four to six, usually five, pairs of round-crested plicae; median three or four pairs often have a low adsulcal costa. Dorsal valve has three or four pairs of sharp-crested plicae, each with a low costa on either side of anterior half.

Ventral micro-ornament of week radial capillae, five per mm. Some evidence of irregular pustules remains, but concentric lirae have been destroyed.

Internal. Dental plates converge ventrally at 65 degrees and adminicula diverge very slightly to the floor of valve, largely buried by secondary thickening in the umbonal cavity. Posterior face above muscle field bears deep groove in GSC 35607, from GSC locality 53705, Peel River area. Muscle field triangular, not highly elevated, short, not rimmed by high ridges or prolonged in front medianly; adductors slightly raised, divided by narrow myophragm (GSC 35607, Peel River); diductors weakly an unevenly striated longitudinally.

GSC 35607, from GSC locality 53705, Peel River area, has a small cardinal process and horizontal small socket plates with low crural plates. The median septum and muscle scars are not seen, perhaps because of poor preservation.

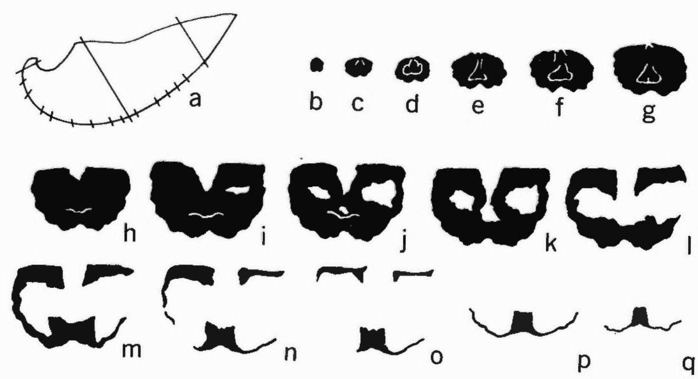

Figure 14. Spiriferella saranae *(de Verneuil), serial sections, GSC 30767, GSC loc. 53710, Jungle Creek Formation, Peel River. Sequence from umbo to anterior margin. Approx. x75.*

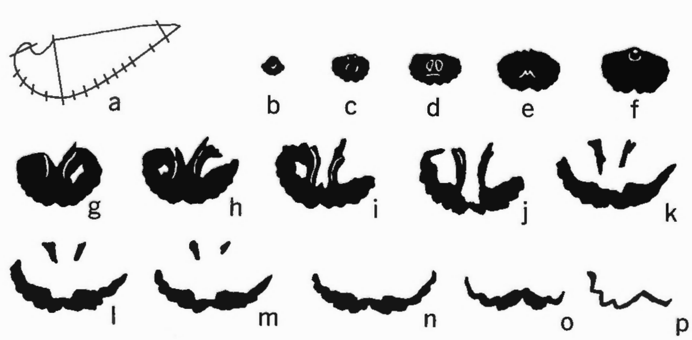

Figure 15. Spiriferella pseudotibetana *Stepanov, serial sections, GSC 30770, GSC loc. 57058, Tahkandit Formation, Tatonduk River. Sequence from umbo to anterior margin. Approx. x75.*

Dimensions

Spec.	Loc.	Width	Length	Dorsal length	Height	Hinge width	Umbonal Angle
				(mm)			(degrees)
(GSC)	(GSC)						
35582	57141	+30	+29		+13.5	27	95
35583	57141	+28.5	+31.5		11	21	90
35584g	57141	26.5	27		14	20	80
35585	57141	+27	+26		+11	22	88
35586	57141	+25	+25.5		+13	19	90
35587	57141	+33	+31		+15	28	?85
35588	53709	20	20.5	16.5	12.5	15.5	80
35589	53709	29.5	29		14.5	23	80
35590	53709	20.5	19		10.5	16.5	90
35591	53709	30	33	22	30.5B	21.5	90
35592	53709	24.5	22.5		9.5	23	95
26944g	53710	23	22		12	18	92
35593g	53710	23	22		9	20	?75
35594	53710	30	25.5		12	28	95
30768	53712	+28	29		+16	28.5	100
30765	53713	33	46	33	30 B	28	100
26945	53713	30.5	+34.5	25.5	29 B	21	
26950	53713	+28	+27		+16	25	85
35595	53713	+21	+21		+10	?16.5	90
35596	53713	23	23		12	18	90
35597	53713	17	16		7	?13	85
35598	56977	+28.5	31		17.5	?24	?100
35599	56977	?28	+37		+20	24	?100
35600	56977	?28	+33		+15		
35602	C-4054	21	19	17	12 B	15	90
26946	53860	34	37	28	29 B	27	90
35601	54011	+27.5	34		16	25	90
35604	53705	18.5	17		8	14.5	?90
35605	53705	16	15.5		8	14	80
35606	53705	18	19		7.5	14.5	80
35607	53705	23	29	24	13.5B	15.5	75
35608	53706	29	34.5		16	28	80
30769*	53707	21.5	+21.5		+8	19.5	90
35609	53720	14	15		6.5	10	70
35610	53720	+18	+15		+8	+12	65
35611	53720	+16.5	+15.5		+6.5	?13.5	?80
35612	53720	26	30.5	19.5	?18	21.5	90
35614	53722	27	+26		14	20	75
35615	53722	19	23	20	14.5B	17.5	?90
35616*	53722	+21	+23		+10	15	80
35617g	56999	17.5	16.5		7	13	?85
	(JBW)						
35619	67	16.5	16		8	?15	95
35618	508	17	17.5		7	?11	?120
35620*	558	23	20		7.5	19	
35621	558	?27	?32		15	?24	85
35622	558	+23	+21		+9.5	14.5	75

* 30769: Muscle width 6 mm, field length 12 mm. 35616: Muscle width 10 mm. 35620: Muscle width 5.5 mm, field length 9 mm.

g Measured from growth line.

Variation. Variation is considerable. Amongst material from the *Yakovlevia* Zone (Ey), specimens at GSC locality 53710 in the Peel River area are costate and have high umbones with concave posterior walls. Two dorsal valves have the fold typical of the species *saranae* not *ordinaria*, which is found at the same place. Cardinal extremities are slightly alate. From GSC locality 53713, Peel River area, specimens are costate, and one shell, GSC 26945, has four or five costae on lateral plicae anteriorly. The cardinal extremities are bluntly angular, and the sulcus is V-shaped anteriorly, with straight sides. On one shell, the fold has a narrow groove; on the other, it has an angular crest.

Shells at GSC locality 56977 (Ettrain Creek area) are typical, having three to five very sturdy costae in the sulcus. Most small ventral valves from GSC locality 53705 (Peel River area) have very sharply angular plicae near the beak, and deeply troughed sulcus, but one specimen is nearer to type. The fold has a narrow median groove and flares abruptly near the anterior margin, and the plicae curve out also. The ventral muscle field is broad and raised in these specimens, with ridges and anterior supporting ridge more slender and less prominent that those in other Yukon material; this is the case also in a specimen from GSC locality 53707, from the Peel River area, which has a groove down the posterior face. Shells from GSC locality 53720 in the Peel River area have narrow ventral umbones, and a slit extends for the length of the dorsal fold in GSC 35612 and 35613. A low myophragm runs the length of the muscle field, and the anterior end is prolonged by a slender ridge (GSC 30769).

One ventral valve from JBW locality 113 near Ettrain Creek has a wide hinge, but otherwise the material is too fragmentary to identify. Specimens from JBW locality 508 near Ettrain Creek are poorly preserved and difficult to identify; plicae are high and have a single costa on the inner flank of the two inner pairs. Elongated specimens from JBW locality 111 from the Ettrain Creek area also are poorly preserved, but a ventral valve (GSC 35624) has a narrow umbo, and a dorsal valve (GSC 35623) has a wide hinge and the fold is grooved for its full length.

Amongst specimens from the *Jakutoproductus* Zone (Ej), numerous ventral valves from GSC locality 57141 of the Ettrain Creek area vary in the definition of the sulcus, which may be gently or sharply concave, and in the strength of the innermost pair of plicae. Specimens from GSC locality 53709 (Peel River) have one median sulcal costa, and virtually no others. They are transverse at early maturity, having a shallow concave sulcus, but are typical at maturity in having a narrow V-shaped sulcus.

Ventral valves from JBW locality 558 (Ettrain Creek) vary in hinge length and have narrow umbones and elongated outline with few costae. The specimen from GSC locality C-4054, Ellesmere Island, has a slit fold and moderately narrow ventral umbo. The plicae are sharply angular near the umbonal tip.

Resemblances. The Canadian specimens are distinctive, characterized by shape and dorsal fold, and closely resemble in their ventral valve and general appearance some shells commonly referred to *Spiriferella saranae* (de Verneuil), originally described from the Irgin Horizon, near Sarana River, Russia.

The original description of *S. saranae* by de Verneuil (1845) from the upper Artinskian of the Ufa River, near Krasnoufimsk, is short and lacks detail but does mention that the sulcus has "five or six smaller, equally spaced" costae. The figured specimen shows a high interarea, a broken but probably enrolled umbo and simple plicae. The figured posterior fragment of the dorsal valve has a narrow fold, with what may be three costae, but no deep median groove, although details are hard to interpret: a median line shown by de Verneuil (1845, Pl. 6, fig. 156) suggests a possible slit in the fold. Of three specimens figured by him in von Keyserling, 1846, Pl. 8, that of figure 5 has two sulcal costae. Two other figured shells are small and have simple plicae and narrow sulcus. From inspection of probable topotypes at the Chernyshev Museum, Leningrad, it appears that *S. saranae* (de Verneuil) is typified by a rounded dorsal fold that bears a shallow median groove.

The ventral umbo is well incurved and posterior walls diverge and extend well forward, imparting a lozenge shape. The specimen described by Chernyshev (1889, Pl. 7, fig. 25) is close to typical *S. saranae* but also resembles *S. pseudotibetana*.

The ventral valve described as *S. saranae* by Chernyshev (1902, Pl. 12, fig. 4, Pl. 40, fig. 7) has a different shape, simple plicae and well rounded dorsal fold. The specimens clearly are allied to *S. timanica* Barkhatova (1968, 1970) from the younger ?Baigendzinian Komichan Horizon of Timan, but they are longer and have a wider, noncostate sulcus. The form is here named *Spiriferella barkhatovae* n. sp. and the specimen figured by Chernyshev (1902, Pl. 12, fig. 4) is selected as holotype.

Spiriferella pseudosaranae Einor (in Likharev and Einor, 1939) has a massive ventral umbo and high posterior walls, shorter than those of many Canadian specimens but close to individuals from GSC locality 53712. The age is likely to be Sakmarian, as it is for the Canadian specimens. But the dorsal valve of *pseudosaranae* from Novaya Zemlya has not been illustrated, and *pseudosaranae* could be the same as associated *S. pseudodraschei* Einor.

The Novaya Zemlya specimen figured as *Spiriferella saranae* by Einor (in Likharev and Einor, 1939, Pl. 22, fig. la, c) is likely to be identical, but no dorsal valve is available for comparison. A ventral valve from King Oscar's Land, Novaya Zemlya, ascribed to *S. saranae* by Holtedahl (1928, Pl. 21, fig. 3), has prominent sulcal costae and may be related.

Shells that closely resemble the Canadian specimens have been named *Spiriferella kolymaensis* Zavodowsky (1970, Pl. 36, figs. 3, 4, Pl. 38, figs. 4-6, Pl. 39, fig. 1). The holotype (ibid., Pl. 38, fig. 4) is especially similar to the Canadian shells, but specimens are less inflated and have a wide hinge and short posterior walls, as seen in specimens from Peel River, Yukon Territory, and Novaya Zemlya. The ventral umbo is slender, as it is in *S. vojnowskii* Ifanova from Timan, and the dorsal groove is distinct and sometimes wide. The species *S. kolymaensis* comes from the Irbichan, and particularly the Yasachnin, horizons of Kolyma River, and thus it is of Sakmarian age also.

Spiriferella bitutchensis Abramov (1974, Pl. 3, figs. 9, 10) from the Echi beds of south Verchoyan may be close, but the dorsal valve has not been described.

An elongate shell with incurved narrow ventral umbo figured by Nelson and Johnson (1968, Pl. 95, figs. 7, 8) as *Spiriferella editiareatus* (Einor) might be either *Spiriferella saranae* or *S. pseudotibetana* as understood in this paper. We observed no Yukon shells like *"Spiriferella" editiareatus* Einor (in Likharev and Einor, 1939, Pl. 25, fig. 8, Pl. 26, figs. 1-4), which has a very faintly plicate ventral valve, as does the 'variety' *shevchenki* Einor (ibid., Pl. 26, fig. 5). Inspection of the types at Leningrad suggests that *editiareatus* belongs to *Gibbospirifer* Waterhouse, as published in 1971 by Bamber and Waterhouse. The fold of these types is high and narrow and has no sulcus, dorsal plicae are strong, and the specimen of their Figure 17, p. 153, indicates that ventral thickening characteristic of *Spiriferella* is lacking.

Spiriferella allied to or identical with *S. saranae* have been recorded from Chitral as *S. rajah* not Salter by Reed (1925) and as *Spiriferella* sp. from Asselian beds of Afghanistan by Legrand-Blain (1968).

Specimens identified as *Spiriferella saranae* de Verneuil from the Belcher Channel Formation (Harker and Thorsteinsson, 1960, Pl. 22, figs. 1, 2, Pl. 23, fig. 8) are similar to the Jungle Creek specimens but cannot be identified with certainty in the absence of the dorsal valve. They might be close to *S. pseudotibetana* Stepanov.

Spiriferella pseudotibetana Stepanov 1937

Plate 4, figures 12-14, 16, 17; Plate 5, figure 1; Figure 15

1937b *Spiriferella pseudotibetana* Stepanov, p. 34, Pl. 1, fig. 7, Pl. 3, figs. 1-3, Pl. 10, fig. 1
1937b *Spiriferella saranae* (not de Verneuil) Stepanov, p. 24, Pl. 2, fig. 1
1937b *Spiriferella saranae simplex* not Grabau, Stepanov, p. 25, Pl. 2, figs. 2, 3
1937b *Spiriferella saranae mongolica* not Grabau, Stepanov, p. 27, Pl. 2, figs. 4, 5
1939 *Spiriferella nalivkini* Kulikov, p. 162, Pl. 5, figs. 2, 3
1971 *Spiriferella* sp. Bamber and Waterhouse, p. 164, Pl. 17, figs. 4, 9, 11
1971 *Spiriferella* cf. *saranae* (not de Verneuil), Brabb and Grant, p. 17, Pl. 1, figs. 13-17

Lectotype (here designated). Specimen figured by Stepanov (1937b, Pl. 3, fig. 2) from the Krasnoufim Horizon, Kolwa Peninsula, USSR; kept at Chernyshev Museum, VSEGEI, Leningrad

Diagnosis. Small, moderately to gently convex, slightly transverse to usually elongate shells; sulcus deep, narrow, V-shaped; fold narrow posteriorly, sulcate and broad anteriorly; plicae well defined, simple, with deep narrow interspaces; muscle platform low.

Material and localities

Loc.	Area	Brach. zone	Valves: Both	Ventral	Dorsal	Lithology
(GSC)						
53939	Tat	Fs		lem		lmst
53940	Tat	Fs		2m		lmst
53944	Tat	Fs		3em, 1m		lmst
53945	Tat	Fs	lem	10em, 2m		lmst
56985	Tat	Fs		?1m		gran. lmst
57058	Tat	Fs		7em, 2m		gran. lmst
57121	Tat	Fs		lem, 2m		breccia
57151	Tat	Fa		lem		ss
57242	Tat	Fa		2em, 1m	lem	grit
57259	Tat	Fa		2m		gran. lmst
57260	Tat	Fa		1i	1j	breccia
C-4018	Ell	Fa-s		2m		coarse lmst
C-4062	Ell	?F		2em, 2m		gran. lmst
C-4079	Ell	Fs-Ej		3i		calc. grit. lmst

Description

External. Ventral valve moderately to gently convex, with massive umbo, usually at 85 to 90 degrees, but over 110 degrees in some specimens from GSC locality 57058, Tatonduk River; posterior walls high, swollen, and typically concave in outline; hinge of moderate width, with obtuse cardinal extremities at nearly 100 to 110 degrees, varying to bluntly acute, near 80 degrees. Interarea moderately to strongly concave. Shell convex longitudinally, maximum width generally placed near anterior third of length. Sulcus at angle of 18 to 20 degrees, either V-shaped or concave in section, widens anteriorly to 23 degrees in some shells, bears median costa and one, two, or even three lateral costae in some specimens, but frequently no costae. Dorsal fold narrow and round-crested posteriorly, widening in front or near midlength and developing a median groove with up to two costae on flanks. Usually three or four pairs of plicae (up to six pairs) high with rounded crests and either very narrow or evenly concave interspaces in ventral valve, may curve out laterally over anterior third of shell. Plicae generally smoothly rounded, rarely with median slit or costae on either inner or outer slope. Micro-ornament on GSC 35733, from the Tatonduk River at GSC locality 57242, shows radial lirae of uncertain density, four to five broad and sturdy pustules per mm, at 25 mm from umbo, others in rows, not alternating in quincunx.

Internal. Sturdy dental plates, converging at 90 degrees to meet broad adminicula diverging at 90 degrees to floor of valve. Muscle field broad posteriorly, adductors depressed, diductors broad, grooved, secondary thickening considerable. Posterior face with low bulge of shell.

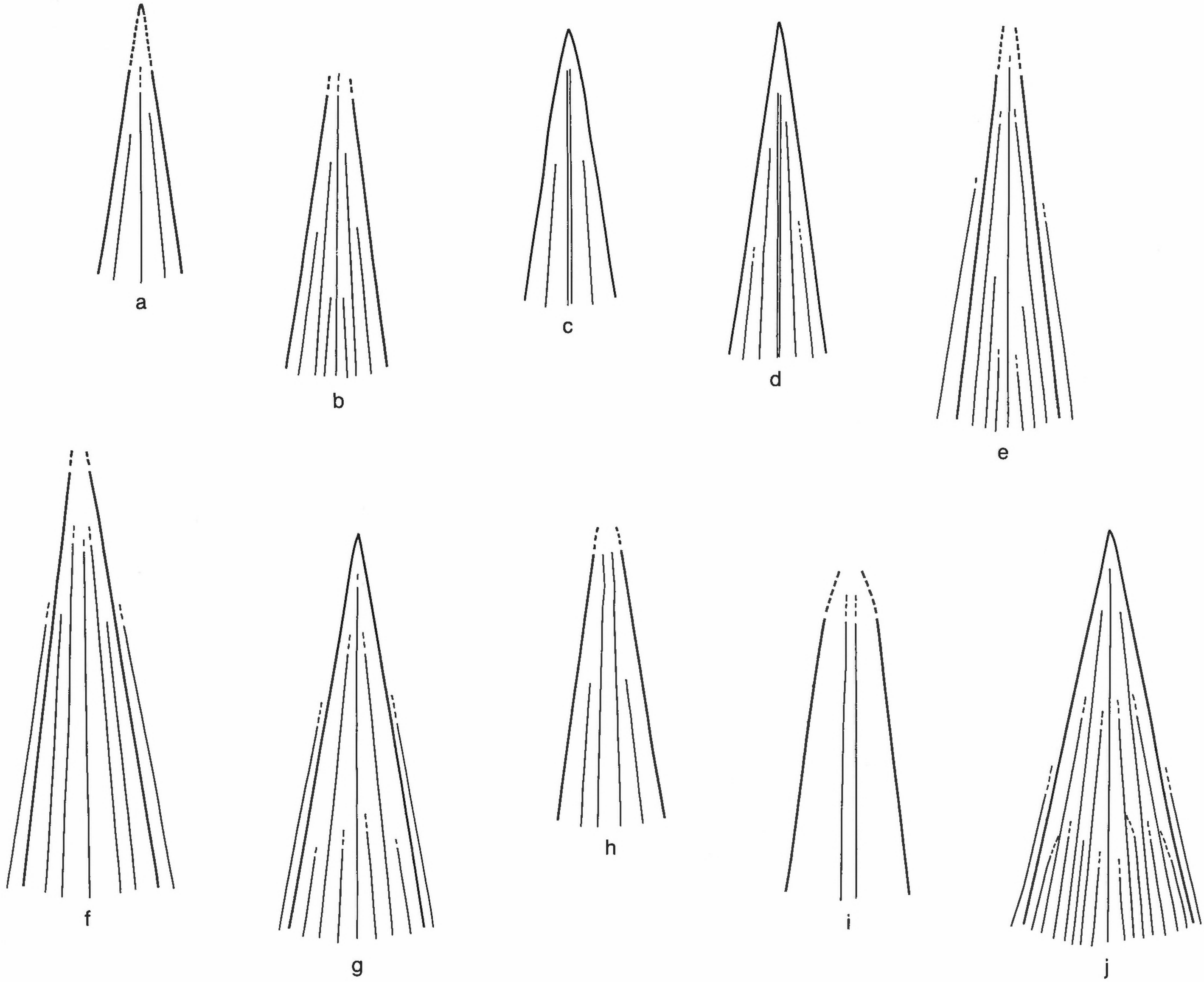

Figure 16. Costal diagram of ventral valves, x1. Spiriferella saranae *(de Verneuil): (a) GSC 30763, GSC loc. 53170, Jungle Creek Formation, Peel River; (c) GSC 26945, GSC loc. 53713, Jungle Creek Formation, Peel River.* S. loveni *(Diener): (b) GSC 30766, GSC loc. 26406, Assistance Formation, Devon Island; (f) GSC 30789, same locality; (d) GSC 30782, GSC loc. C-4024, Assistance Formation, Ellesmere Island.* S. keilhavii *(von Buch): (e) GSC 30777, GSC loc. C-4019, Assistance Formation, Ellesmere Island; (g) GSC 30794, GSC loc. C-4016, Assistance Formation, Ellesmere Island; (h) GSC 30805, GSC loc. C-4063, new formation, Ellesmere Island; (i) GSC 30812, GSC loc. C-6136, unnamed formation, Ellesmere Island.* Elivina cordiformis *n. sp.: (j) GSC 30797, GSC loc. 53838, unnamed beds, north Richardson Mountains.*

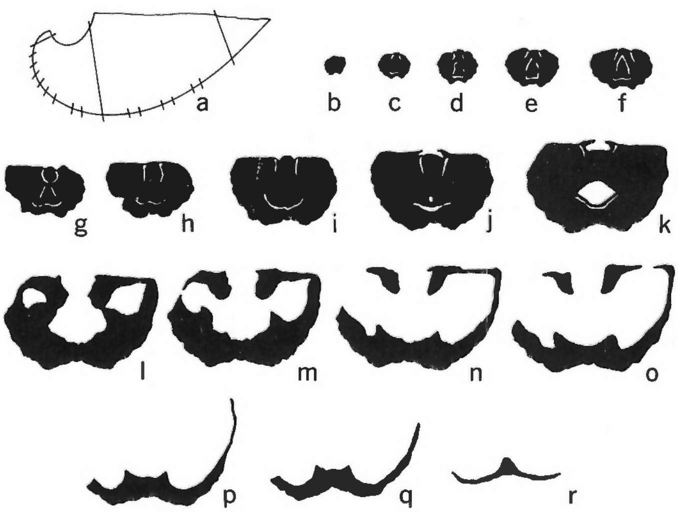

Figure 17. Spiriferella loveni *(Diener), serial sections, GSC 30792, GSC loc 56979, Tahkandit Formation, Tatonduk River. Sequence from umbo to anterior margin. Approx. x75.*

Dimensions

Spec.	Loc.	Width	Length	Height	Hinge width	Umbonal angle
			(mm)			(degrees)
(GSC)	(GSC)					
27003	53945	24	+25	10.5	?19	90
30771	C-4018	33	33	16.5	30.3	92
30772	57058	30.5	30.3	13	27.5	120
35625	C-4018	?33	+26	12	?31	95
35630	C-4062	20	18.5	9	17	85
35631	C-4079	13	11	5	11	90
30773	57259	28	34	17	26.5	
35632	57260	16	14.5	7.5	?13	85
35633*	57260	7		2.7	7	
35634	57242	+17.5	+17	9.5		
35635	57242	+17.5	18	7.5	?16	85
35636*	57242	21		4.3	17	
35637	57058	22.5	23	10	?19.5	85
35638	57058	+22	+21	+8.5	?19	
35640	53944	+22	+23	11.5	?18	80

*27003: Muscle field width 7.5 mm. 35633: Dorsal length 5.2 mm. 35636: Dorsal length 16 mm.

Variation. GSC 35641 from GSC locality 57121, Tatonduk River, is unusual because it has seven sulcal costae and up to three costae over plicae. Its umbo is massive but hidden in matrix.

Resemblances. The specimens are identified tentatively with *Spiriferella pseudotibetana* Stepanov from general shape and ornament and from dorsal fold with groove.

Associated specimens, figured from the Kolwa region, northern Urals, by Stepanov (1937b, Pl. 2, figs. 2, 3) as *Spiriferella saranae simplex* Grabau, are somewhat similar to typical *S. pseudotibetana* in shape, and they might be allied. They lack costae and are not well enough preserved to allow certain identification. Grabau's specimen of *simplex* (Grabau, 1931, Pl. 20, fig. 1) from the Jisu Honguer Formation, Mongolia, is transverse and its hinge is wide. The Kolwa specimen figured as *Spiriferella saranae mongolica* Grabau by Stepanov (1937b, Pl. 2, figs. 4, 5) is similar also in shape and ornament and has a slit in the dorsal fold. The original specimens of *S. salteri mongolica*, named by Grabau (1931, Pl. 20, figs. 3-6, Pl. 23, fig. 4, Textfigs. 45-50) from the Jisu Honguer Limestone of Mongolia, have concave posterior walls and narrow subequal plicae. Other Kolwa specimens, which Stepanov (1937b, Pl. 2, figs. 8a-c, 9) referred to *S. saranae draschei* (Toula), are poorly preserved, large shells with well defined narrow or wide groove in the dorsal fold, and though possibly unusual *S. pseudotibetana*, they also look like an ally of *S. keilhavii* and were perhaps ancestral.

A dorsal view of *Spiriferella* figured as *S. saranae* by Chernyshev and Stepanov (1916), from Artinskian beds near Krasnoufimsk, shows a flat dorsal fold with a slight groove and possibly a median costa; it may well belong to *S. pseudotibetana*.

An Artinskian shell from the Sarwa River, figured by Chernyshev (1889, Pl. 7, fig. 25) as *S. saranae* (de Verneuil) and as *S. salteri* Chernyshev (1902, Pl. 6, fig. 5), has a well defined narrow groove, at least anteriorly and possibly for the full length. Its identity is not certain.

Spiriferella nalivkini Kulikov (1939, Pl. 5, figs. 2, 3) from the *Parafusulina lutugini* beds (Baigendzinian) of the Urals is likely to be conspecific with the Canadian shells; it is regarded provisionally as conspecific with *S. pseudotibetana* because it has a deep ventral sulcus, a moderately incurved ventral umbo, a fold with a shallow groove or flattening, and costae arising anteriorly. A very narrow shell, it has narrow plicae, so that the general appearance differs from the Yukon material, but this may prove to be of no specific significance.

Brabb and Grant (1971, Pl. 1, figs. 13-17) figured as *S. saranae* a small *Spiriferella* from the sandstone unit at the base of the type Tahkandit Formation, eastern Alaska. The fold is damaged, hindering identification, but the ventral valve looks like that of Tatonduk specimens assigned to *S. pseudotibetana*. The age of the sandstone unit has not yet been established, but it is likely to be Baigendzinian or Kungurian.

It is considered here that *S. pseudotibetana*, a descendant of *S. saranae*, differs from it in being slightly rounder and having a slightly shallower groove in the dorsal fold.

Spiriferella vaskovskii Zavodowsky 1968

1968 *Spiriferella vaskovskii* Zavodowsky, p. 156, Pl. 45, figs. 1, 2
1968 *Spiriferella saranae* (not de Verneuil), Nelson and Johnson, p. 729, Pl. 93, figs. 8-10, not 1-7, Pl. 96, fig. 9
1970 *Spiriferella vaskovskii* Zavodowsky, Zavodowsky, p. 160, Pl. 50, figs. 8, 9, Pl. 5, figs. 1-4

Holotype (by original designation). Specimen figured by Zavodowsky (1968, Pl. 45, figs. 1, 2); kept at Chernyshev Museum, Leningrad

Diagnosis. Moderately large shells that have narrow and shallow sulcus, low fold without median groove, and costae arising anteriorly; plicae broad, interspaces narrow.

Discussion. Specimens figured by Nelson and Johnson (1968) appear to be identical with the ventral valves figured by Zavodowsky (1968, 1970) from the Djeltin horizon (Baigendzinian), northeastern Siberia. The Yukon shells come from the Mount Burgess section and are poorly dated, but possibly they are of Baigendzinian age.

Three specimens of Sakmarian or greater age, reported by Nelson and Johnson (1968) from their Tatonduk River section in the Jungle Creek Formation, are not figured and presumably are not conspecific. Other Canadian specimens that Nelson and Johnson (1968, Pl. 93, figs. 1-7) assigned to *Spiriferella saranae* are similar to *S. saranae*.

Spiriferella timanica Barkhatova (1962, Fig. 2x; 1970, Pl. 20, figs. 1-4) is similar to *S. vaskovskii* but apparently has no median costa in the sulcus, unlike *vaskovskii* or the Canadian shells. It comes from the Baigendzinian Komichan horizon of Timan, and Barkhatova (1970) included in synonymy a shell figured as *Spirifer saranae* by von Keyserling (1846, Pl. 8, fig. 5). *Spiriferella timanica* apparently differs from *S. vaskovskii* in possessing a more rounded, less costate dorsal fold, but the dorsal valve of the Canadian material is not known. The shell from Petchora Basin, assigned to *S. saranae* by Ifanova (in Ifanova and Semenova, 1972, Pl. 11, fig. 3), appears to be similar to *S. timanica*, especially the specimens figured from the Lower Permian of the Urals by Chernyshev (1902, Pl. 12, fig. 9, Pl. 40, fig. 7, Textfigs. 40-45) as *Spiriferella saranae* (not de Verneuil).

Spiriferella ?loveni (Diener 1903)

Plate 5, figures 2-17; Plate 6, figures 1, 2;
Figures 16b, d, f, 17, 18

1873 *Spirifer* sp. indet. Toula, p. 273, Pl. 2, figs. 1, 2
1875 *Spirifer parryanus* Toula, p. 256, Pl. 7, fig. 8a-d

1903 *Spirifer loveni* for *S. parryanus* Toula 1873 not Hall 1858, Diener, p. 17
1914 *Spiriferella keilhavii* (not von Buch), Wiman, p. 26, Pl. 2, figs. 25 - 30, Pl. 3, fig. 1
1931 *Spiriferella parryana* (Toula), Frebold, p. 18, Pl. 5, figs. 5, 6
1937 *Spiriferella saranae* (not de Verneuil), Frebold, p. 45, Pl. 11, figs. 7, 8
1955 *Spiriferella parryana* (Toula) = *keilhavii* (von Buch), Dunbar, p. 139, Pl. 27, figs. 10, 11, 13, 14
1960 *Spiriferella saranae* (not de Verneuil), Harker, in Harker and Thorsteinsson, p. 71, Pl. 22, figs. 4 - 8 (part, not figs, 1, 2, ?3)
1960 *Spiriferella keilhavii* (not von Buch), Harker, in Harker and Thorsteinsson, p. 72, Pl. 22, figs. 9 - 11, Pl. 23, figs. 1, 2
?1964 *Spiriferella* aff. *interplicata* (not Rothpletz), Gobbett, p. 155, Pl. 20, figs. 4 - 6
1971 *Spiriferella* sp. Stehli and Grant, p. 518, Pl. 64, figs. 36 - 43

Diagnosis. Large shells, moderately convex, whose maximum width is generally placed near anterior third but sometimes at hinge, ventral umbonal angle 75 to 110 degrees (close to 100 degrees generally), lateral flanks moderately steep; sulcus broad, shallow, with five to seven costae; four or five pairs of costate dorsal plicae; five to seven pairs of ventral plicae showing highly variable costal pattern. Dorsal fold with deep median cleft, from no lateral costae to a few. Ventral muscle platform raised high above floor of valve anteriorly.

Material and localities

Loc.	Area	Brach. zone	Valves Both	Ventral	Dorsal	Lithology
(GSC)						
C-1886	Ell			1j, 4i, 2em, 5m	1m	shelly skel. lmst
C-3993	Ell	F		3m		fine ss
C-3996	Ell	Gc		1em		fine green ss
C-4002	Ell	F		1i, 2em, 1m		fine ss
C-4004	Ell	Gc		1i, 2em, 1m		sandy sls
C-4014	Ell	?Gc		3i, 3em, 2m		silty ss
C-4015	Ell	Gc		2em, 3m		green med. ss
C-4020	Ell	?Gc		3em, 5m		calc. green ss
C-4021	Ell	Gc	1m	1i, 4m		calc. green ss
C-4024	Ell	?Fps	1m	?1m		green ss
C-4025	Ell	F		2i, 2em, 1m		silty fine lmst
C-4026	Ell	?Gc		1m		
C-4035	Ell	?F		1em		finely gran. lmst
? C-4060	Ell	Fs-Fl		2j		gran. lmst
C-4061	Ell	Fs-Fl		1j, 3i, 2em, 1m		gran. lmst
? C-4072	Ell	Fl		5em		shelly fine lmst
? C-4073	Ell	Fl		1em, 4i		fine lmst
C-6639	Yuk	F-G		1em, 5m		breccia
26406	Dev	Fps	2em	5em, 4m		fine ss
53931	Tat	Fps		6i, 1em		coarse skel. lmst
53932	Tat	Fps		5em		coarse skel. lmst
56925	Tat	Fps		1i, 2em		fine lmst
56979	Tat	Fps		3em		fine lmst
57152	Tat	Fps	5em	6i, 5em	1i	fine lmst
57244	Tat	Fps	1em	6em		?calc. ss
57687	Ell	Gc?	1m	1j, 1i, 4em, 3m	1em	green sand
57720	Ell	?Fl		2i, 2m		coarse skel. lmst
58973	Ell	Fps	2m	7em, 5m		shelly, finely gran. lmst

Description

External. Shells large, generally slightly wider than long, sometimes elongate; maximum width placed in anterior third. Ventral valve moderately convex; umbonal region swollen, prominent, incurved, comprising one-third of valve length. Tip of umbo small, sharply incurved; umbonal angle variable, but generally close to 100 degrees. Interarea flat to slightly concave; interarea length about 0.2 of hinge width; delthyrium has angle of 75 to 80 degrees, closed by gently convex deltidium arched toward beak. Lateral flanks slope at 50 degrees to commissure near hinge, strongly concave in outline. Dorsal valve gently convex, subrectangular in outline.

Sulcus shallow, the floor evenly concave to V-shaped; sulcal angle 20 degrees at 10 mm from umbo, tends to decrease slightly with increased distance from umbo. Sulcus has a median costa and one to three costae on each sulcal flank. Fold well defined; crest with broad, deep, median groove arising at or near umbo. Fold high anteriorly; generally each flank of fold has one to three low costae in anterior two thirds of valve, but some have none.

Ventral valve has five or six, rarely seven, pairs of plicae; dorsal valve has four or five pairs. The inner three pairs of dorsal plicae may divide at midlength into three costae, the central one being the largest. Inner side of two to four pairs of ventral plicae have a low costa on the adsulcal and occasionally the absulcal side; extent and range of costae highly variable (see Fig. 18) and not always symmetrical. No apparent grouping of costal pattern by age or locality.

Ventral micro-ornament of fine pustules aligned radially and lying on fine wavy growth lamellae; density of pustules 12 to 14 in 5 mm longitudinally, 15 in 5 mm transversely. About 16 growth increments in 1 mm, and three increments produce a pustule in many Yukon specimens, but are obscure in Arctic material. In GSC 35706 (GSC loc. 57244), from Tatonduk River area, five or six capillae and up to 40 growth increments per mm with pustules formed from only two or sometimes three growth increments. In GSC locality 57152, Tatonduk River, six radial capillae per mm at 10 mm from umbo, bearing four or five broad, sturdy pustules per mm, often in rows.

Internal. Ventral valve has strong thick dental plates, which diverge anteriorly at 40 to 50 degrees and inward at 40 degrees in shells from GSC locality 26406; adminicula diverge at 75 degrees. Muscle field on a heart-shaped platform with outward-sloping sides, which meet and project as a short, low median ridge anteriorly; anterior borders converge at 50 to 70 degrees and posterior end enclosed by adminicula, which extend as much as one third the length of platform. Adductors long, narrow, together about 2 mm wide, either raised or depressed, separated by a faint myophragm in some shells. Diductors longitudinally striated, three striae per mm, for anterior two thirds of muscle platform. GSC 35707, from GSC locality 57244, has low myophragm and deep, short groove on posterior face. Adductors depressed, divided from diductors by low ridge, as in GSC 35708, from GSC locality 57152 of the Tatonduk River area.

Secondary thickening frequently invades posterior end of muscle platform, burying adminicula and, in old specimens, raising floor of valve almost level with muscle platform. Inside of valve irregularly covered with fine pits, about one per mm^2.

GSC 30774, from GSC locality 57152, Tatonduk River, has large cardinal process with about 24 vertical laminae, horizontal socket plates, vertical crural plates diverging forward widely, and median septum of uncertain length. Spire directed anteriorly in GSC 30795 from GSC locality 26406, Devon Island, but laterally directed in GSC 35693 from same locality.

Dimensions (in mm)

Spec.	Loc.	Width	Length	Dorsal length	Height	Hinge width	Umbonal angle (degrees)
(GSC)	(GSC)						
35628	C-4061	+20.5	+17		+ 5.5	+19	
35629	C-4061	+13.3	+ 9.3		3	11	95
35642	C-4004	47	53		24	32	100
35670	C-1886	+36	27		10		110
35671*	C-1886	+38	?37		?12	?32	
35672	C-1886	+35	22.5		5	+35	
35673	C-3996	+35	+33		13		110
35674	C-4004	34	31		13	33	75
35675	C-4014	25	27		11.3	23.5	
35676	C-4015	+39.5	+33		+13	?33.5	?100
35643	C-4015	56	?57		+31	?40	
35678	C-4020	+42	+38		19.5		100
35680	C-4021	48	37		20	?40	90
35681	C-4024	56	39		19	49	102
35683	C-4061	45	50		28.5	42	90
35684	58973	37	41		16	28.5	100
35685	58973	+42	+43		19	40	105
35686	58973	70	54		25	45	90
35687	58973	51.5	52.5		26	45	100
35688	58973	54	48		22	48	?100
35689*	58973	67	57.5	37	45 B	55	95
35690	58973	64	57	?48	?41 B	52	95
30789	26406	44	+39		17	33	?95
30786	C-4024	52	47.5	37	31.5B	39	?90
						(*keilhavii*?)	
35626	C-4060	12	12.5		5	9.5	70
35627	C-4060	15	15		8.5	11	?70
35650	C-4025	41	43		20	31.5	95
35694	57720	28	28		11	24	?85
35695	57720	+45	+38		+15.5	?35.5	105
35696	57687	+44	+37		+21	?34.5	100
35697	57687	41	48		21	41	110
35698	58968	+22.5	+20.5		+10.5	?20.5	90
35699	C-6639	+41	+38		11.5	40	110
35700*	C-6639	69	?57		?30	?51	
35701	C-6639	53	68.5		33	41	
35702	57224	+30	+29.5		+12.5	22	90
35703	57244	+28	+27		+13	22	75
35704	57244	30	?33.5	27	22.5B	23	
35707	57244	33	29.5		12.5	24	?85
35708	57152	26	26	21	19 B	20.5	80
35709	57152	25	26	19	16 B	19	75
35710	57152	20	17.5		8.5	19	75
30774	57152	24.5	24		11	19	?85
35712	56925	17	14		6	13.5	90
(GSC)	(GSC)						
35713	53932	36	37.5		18.5	28.5	
35714	53932	27	30		12.5	?20	
27014	53932	27	33		14.5	?22	
35715	C-3995	28		18	7	25	
35717	C-4072	26	23.5		11	18	65

* 35671: Muscle width 10.3 mm, field length ?13 mm. 30789: Muscle width 11 mm, field length ?15.5 mm. 35700: Muscle width 18 mm, field length ?29 mm.

Variation. Shells within single collections vary considerably in costation and in outline from transverse to, less usually, elongate. Specimens from the Tahkandit Formation of the Tatonduk River section at GSC localities 57152 and 57244 are smaller than those from the Assistance Formation of Devon Island (GSC loc. 26406), and are oval or weakly transverse, with a slender ventral umbo and costate sulcus and fold. The dorsal groove is well defined (deeper than suggested on Pl. 5, fig. 10), and commences at the umbonal tip, unlike that of *keilhavii*, but perhaps this identification may be in error, and the specimens are either a different species or a variant of *keilhavii*. Shells from GSC locality 56979, Tatonduk River, are similar but lack dorsal costae. Specimens from GSC localities 53931 and 53932 on the opposite limb of the syncline in the Tatonduk River section (see Bamber and Waterhouse, 1971, Fig. 7) lack costae, and have a variable, generally wide, ventral umbo, and some are unusually elongate.

Very large ventral valves from GSC locality C-6639 from unnamed beds of the Richardson Mountains have very thick shell, huge muscle field, massive umbones and very low plicae. They are found in breccia and their unusual appearance probably reflects a very active habitat.

Specimens from the Trold Fiord green sandstone of Ellesmere Island (GSC locs. C-4014, C-4015, C-4020, C-4021 and 57687) generally have fewer costae than shells from GSC loc. 26406, but otherwise they differ little. Shells from dark, dense siltstone at GSC locality C-3993, Ellesmere Island, have large simple plicae with two sulcal costae, and no medial costa.

Immature ventral valves from Ellesmere Island, at GSC localities C-4060, C-4072, C-4061 and C-4073, may be conspecific but are very difficult to identify with confidence, as neither the mature shape nor the dorsal valve are known. The shells from GSC locality C-4060 are small and have extended umbones. The specimens from GSC locality C-4072, Ellesmere Island, in the *Lissochonetes* Fl Zone have narrow umbones, concave posterior walls and simple high plicae with wide interspaces. They resemble fragments figured as *Spiriferella* sp. by Stehli and Grant (1971), collected by Stehli from near the Svartevaeg Cliffs of Axel Heiberg Island (locality uncertain), at an unmeasured height above the base of an undetermined formation of unknown stratigraphic position. The age was thought to be somewhere within the four substages of the "Wordian Series", and was incorrectly shown as Kazanian by Cooper and Grant (1973). It is in fact Nevolin, i.e., mid-Kungurian.

Amongst other specimens from Ellesmere Island is the large fragment of a ventral valve from GSC locality C-4073, which has two sulcal costae. Ventral valves from GSC locality C-4061 are transverse and have rounded plicae with very narrow interspaces, as in shells from the Trold Fiord Formation at GSC locality C-4015.

Resemblances. This species is identified readily from the distinctively sulcate fold of the dorsal valve. The ornament varies considerably and the shape, though generally transverse, is not of prime diagnostic value. First of such shells to be named definitely was *Spirifer parryanus* Toula from the Middle Permian of Spitzbergen. Diener (1903, p. 17) pointed out that *Spirifer parryanus* Toula 1875 was preoccupied by a Devonian form *Spirifer parryanus* Hall 1858. He proposed the name *loveni* as substitute. After inspecting Toula's types (three ventral valves and a dorsal valve), Diener (1903) expressed doubt over the identity of the dorsal valve; he reported that Toula's figure showed alate extremities that are not preserved in the original.

Subsequently this species *Spiriferella parryana* = *S. loveni* apparently became confused with *Spiriferella keilhavii* (von Buch), which may have a ventral valve similar in shape and ornament, but is distinguished by its low dorsal fold with a shallow median groove posteriorly or none at all. Wiman (1914) was the first to synonymize the two species and Dunbar (1955) followed his lead. In an excellent and thorough study Miloradovich (1936) defended the validity of the species, but his own figured shells may prove to be *Alispiriferella gydanensis* (Zavodowsky). Frebold (1931) and Stepanov (1937a) also noted the probable taxonomic significance of the grooved fold.

Among the 'species' of *Spiriferella* from the "*Spirifer* Limestone" of Spitzbergen recorded by Stepanov (1937a) was *Spiriferella keilhavii parryana* (ibid., Pl. 7, fig. 11), which has a dorsal fold bearing a very wide groove, perhaps as in *Alispiriferella gydanensis* (Zavodowsky). Other specimens, figured as *keilhavii lita* Frederiks (ibid., Pl. 7, fig. 7, Pl. 8, figs. 1 - 4) and *polaris* (Wiman) (ibid., Pl. 8 , figs. 5 - 8), all have simple rounded plicae suggestive of *Spiriferella polaris* (Wiman). This identification is supported by their association with a dorsal valve with rounded fold, identified as "*Spiriferella vercherei* Frederiks" not Waagen by Stepanov (1937a, Pl. 8, fig. 11).

Frebold (1937, Pl. 11, fig. 6) figured a ventral valve from Spitzbergen as *Spiriferella parryana*, which may well be conspecific, but details of the dorsal valve are lacking.

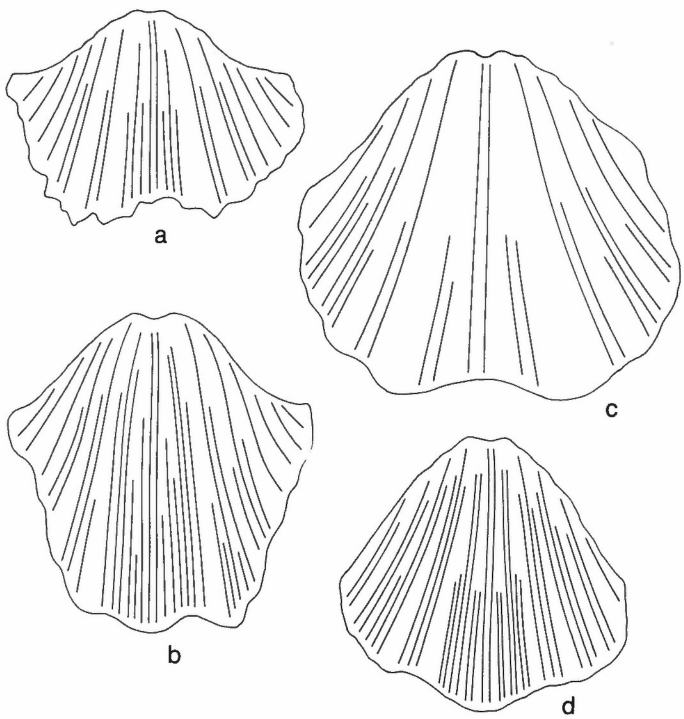

Figure 18. Variation of costation in Spiriferella loveni *(Diener): (a) GSC 30793, GSC loc. 53932, Tahkandit Formation, Tatonduk River; (b) GSC 13767, GSC loc. 26406, Assistance Formation, Devon Island; (c) GSC 30785, GSC loc 58973, Assistance Formation, Ellesmere Island; (d) GSC 30786, GSC loc. C-4024, Assistance Formation, Ellesmere Island. Approx. x75.*

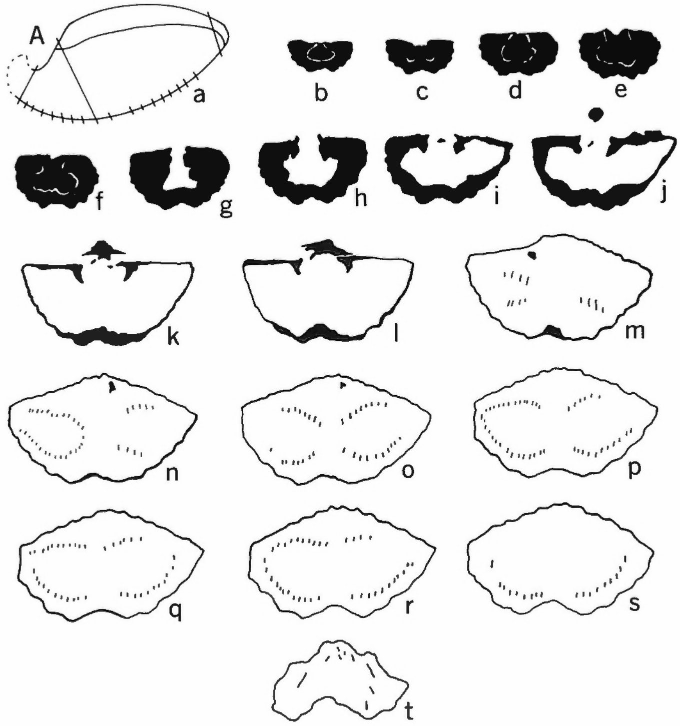

Figure 20. Alispiriferella ordinaria *Einor, serial sections, GSC 30756, GSC loc. 53714, Jungle Creek Formation, Peel River. Sequence from umbo to anterior margin. Approx. x75.*

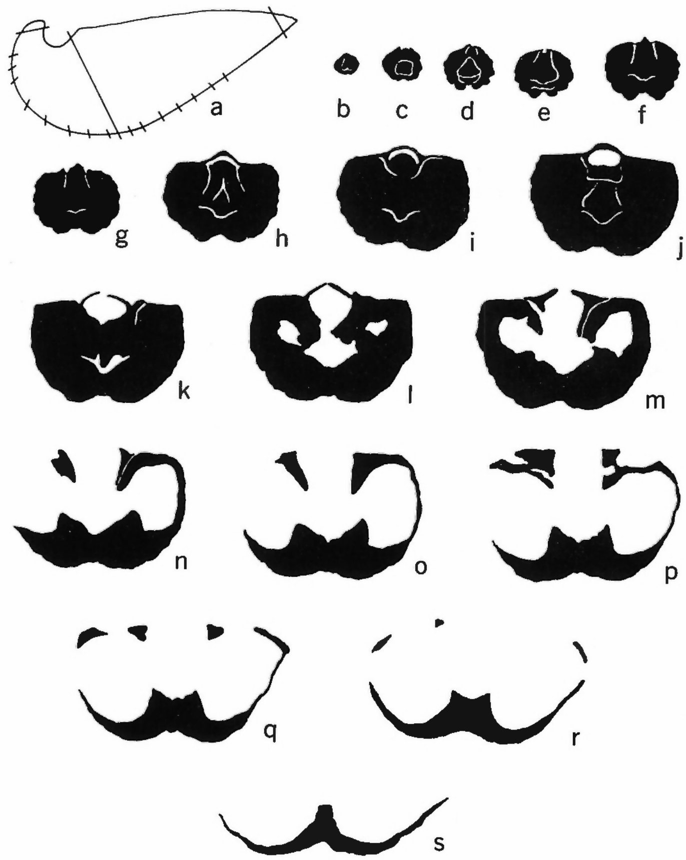

Figure 19. Spiriferella keilhavii *(von Buch), serial sections, GSC 30781, GSC loc. C-4081, ? Belcher Channel Formation, Ellesmere Island. Sequence from umbo to anterior margin. Approx. x75.*

Other specimens from Spitzbergen that were ascribed to *Spiriferella saranae* (de Verneuil) are typical *loveni* (Frebold, 1937, Pl. 11, figs. 7, 8). A transverse specimen with simple ribs, figured as *S. keilhavii*, may be conspecific with *S. loveni parryana* (Frebold, 1937, Pl. 11, fig. 9) but it looks like *S. keilhavii*. The specimens from Nathorstfjord, Greenland figured as *parryana* by Frebold (1931, Pl. 5, figs. 5, 6) appear to belong to *S. loveni*.

Unidentified ventral valves in a block from Cape Stosch, eastern Greenland, figured by Frebold (1933, Pl. 4, fig. 24), look like those of *Spiriferella parryana* (Toula) = *loveni* (Diener) but this is not certain. *S. keilhavii* also is known from this area (Dunbar, 1955). Ventral valves from Traill Island, eastern Greenland, assigned to *Spiriferella parryana* by Frebold (in Frebold and Noe-Nyegaard, 1938, Pl. 1, figs. 10, 11), may be conspecific, but certainty is impossible without the dorsal valve.

Spitzbergen shells from the Middle Brachiopod Chert, described by Gobbett (1964) as *Spiriferella* aff. *S. interplicata* (not Rothpletz), are rather small, somewhat like *Spiriferella gydanensis* Zavodowsky (now *Alispiriferella*, described below). But they could prove to be *S. loveni*, judging from their similarity to small *S. loveni* found in the Assistance Formation. Larger

Spitzbergen by Stepanov (1936, Pl. 5, figs. 1, 2, 3), they are difficult to identify with certainty, and could belong to *S. loveni* (Diener). One specimen from Tempel Bay, Spitzbergen, assigned by Stepanov (1937a, Pl. 8, fig. 10) to *S. draschei*, is typical *S. keilhavii*, the other is narrow and inflated and incurved, and of uncertain affinities (ibid., Pl. 8, fig. 9). Ventral valves ascribed to *S. keilhavii* by Nelson and Johnson (1968, Pl. 96, figs. 7, 8, 12) may be *keilhavii*, but could prove to be *S. loveni*. The same applies to Djigdalin (i.e., Kungurian) ventral valves identified by Zavodowsky (1970, Pl. 69, fig. 4a, b) as *Spiriferella keilhavii* from northeastern Siberia. *Spiriferella kovechovi* Zavodowsky (1970, p. 163, Pl. 70, figs. 4, 5a, b), from the Omolon beds of Kazanian age, is based on ventral valves that might be *keilhavii*. Mid-Permian specimens from the Kolyma massif of northeastern Siberia may be conspecific. They were identified as *Spiriferella rajah* non Salter by Asfanasjeva and Simakov (1970, Pl. 14, figs. 6 - 8). Apparently typical specimens as old as Baigendzinian were figured by Ifanova (in Ifanova and Semenova, 1972, Pl. 11, figs. 4 - 7) as *draschei* from the Talatin Suite of Petchora, though the Talatin Suite has been correlated with the Kungurian by Ustritsky (1971). The dorsal groove is long in one shell, shorter in another; the shells are slightly narrower than is usual for *keilhavii*.

Ventral valves from Great Bear Cape, Axel Heiberg Island, figured by Chernyshev and Stepanov (1916, Pl. 9, fig. 2) as *Spiriferella draschei*, as *S. saranae* (Pl. 11, fig. 1), and as *S. keilhavii* (Pl. 11, figs. 2,3), may be conspecific, that of "*draschei*" being especially typical. A supposed *S. parryana* (=*loveni*) (ibid., Pl. 11, fig. 4) is probably *S. keilhavii*. The ventral valves figured as *S. parryana* (ibid., Pl. 12, figs. 1 - 3) may be *S. keilhavii* or *S. parryana* (=*loveni*). However, all could belong to one species.

A ventral valve from lower Middle Permian beds at horizon G 300 in Amdrupsland, northern Greenland, figured as *Spiriferella saranae arctica* (Haughton) by Frebold (1950, Pl. 6, figs. 1, 1a), is moderately close and may prove to be conspecific.

Nelson and Johnson (1968, Pl. 94, figs. 1 - 15, Pl. 95, figs. 1 - 4, Pl. 96, figs. 1 - 3, 11) assigned typical *S. keilhavii* specimens to *Spiriferella rajah* (not Salter) subsp. B. These were stated to have a smooth-crested brachial fold, unlike *S. rajah* subsp. A, which has two close-set costae along the crest (Nelson and Johnson, 1968, Pl. 94, figs. 1 - 15, Pl. 96, fig. 10). These specimens seem somewhat variable, but include specimens of *S. keilhavii*. Nelson and Johnson (ibid., p. 736, Pl. 96, figs. 7, 8, 12) ascribed ventral valves from the upper Tahkandit Formation of the western Mount Burgess section to *S. keilhavii* but the absence of the dorsal valve makes identification uncertain.

Spiriferella burgaliensis Zavodowsky (1968, 1970) from the Djigdalin horizon of northeastern Siberia, Omolon Basin, appears to be similar to, perhaps identical with, *S. keilhavii*, though it has a deeper groove in the dorsal fold. Zavodowsky (1970, p. 163, Pl. 69, fig. 4) figured a ventral valve, from the same Djigdalin horizon, as *S. keilhavii*, and a ventral valve from the Djeltin beds (Zavodowsky, 1968, p. 166, Pl. 50, fig. 6) as *S. keilhavii keilhavii*, but the lack of dorsal valves precludes definite identification.

Brabb and Grant (1971) illustrated typical *S. keilhavii* as *S. draschei* (Toula), from the limestone unit of the upper Tahkandit Formation of Alaska, some 48 km west of the Tatonduk River specimens described herein.

Spiriferella cf. *vojnowskii* Ifanova 1972

Plate 7, figures 12 - 14

cf. 1972 *Spiriferella vojnowskii* Ifanova, in Ifanova and Semenova, p. 139, Pl. 12, Figs. 6, 7, Pl. 13, figs. 1, 2

Holotype (by original designation). Specimen figured by Ifanova (in Ifanova and Semenova, 1972, Pl. 12, fig. 6); kept at Chernyshev Museum, VSEGEI, Leningrad

Diagnosis. Moderately large shells, with prominent ventral umbones, posterior walls strongly concave in outline, cardinal extremities well rounded. Dorsal fold almost smooth, with anterior very shallow median groove.

Material and locality. Two ventral valves and one specimen with valves conjoined, from GSC locality C-6174, Kandik River, Yukon Territory.

Description

External. Shells of moderate size, ventral umbo prominent, moderately incurved, posterior walls very concave in outline, ventral interarea high. Dorsal umbo unusually prominent, cardinal extremities bluntly obtuse or rounded, at angle close to 120 degrees. Ventral valve has broad-floored sulcus with angle of 17 degrees, bearing prominent median costa. Dorsal fold high, with narrow crest and smooth flanks, and shallow median groove anteriorly. Both valves have five pairs of plicae, bearing broad costae anteriorly on the inner two pairs but largely smooth. Dorsal plicae more costate. Details of micro-ornament not revealed.

Internal. Ventral muscle field slightly elongated, adductors raised. Dental plates large, adminicula high but largely buried. Cardinal process wide, with vertical laminae; socket plates horizontal, arched inward; crural plates subhorizontal.

Dimensions

Spec.	Width	Length	Height Ventral	Height Both	Hinge width	Umbonal angle
			(mm)			(degrees)
(GSC)						
35724	+33	+26	+11.5		29	100
35725	42.5	39.5	19		?36	100
35726*	44	40	?22	30	38.5	80

All from GSC loc. C-6174.
*35726: dorsal length 32 mm.

Resemblances. These specimens agree fairly well in shape, size and ornament with *Spiriferella vojnowskii* Ifanova from the Kungurian Adzvin Suite of Petchora. The types, inspected at Leningrad, are less inflated with a low ventral umbo and median dorsal groove.

Spiriferella leviplica n. sp.

Plate 7, figures 5 - 11

Etymology. (Latin) *levis*, smooth; *plicare*, to fold

Holotype. GSC 30799 from GSC locality C-4074 (Pl. 7, figs. 6 - 8)

Paratopotype. GSC 30798

Diagnosis. Medium large, slightly transverse, moderately convex shells, having five ventral pairs and four dorsal pairs of widely spaced, high, simple plicae; sulcus broad, fold bifurcates at umbo, wide anteriorly; ventral muscle field not strongly elevated.

von Buch's specimens; from *Productus* Sandstone, Mount Misery, Bear Island.

Diagnosis. Large, elongate shells, maximum width in anterior third of shell length; ventral umbo about 0.25 length of shell, interarea large, concave, lateral flanks steep. Sulcus broad, shallow, with seven to fifteen costae; both valves have up to five pairs of costate plicae. Fold low to high, no groove posteriorly, groove shallow, narrow to wide in front, fold costate.

Material and localities

Loc.	Area	Brach. zone	Valves: Both	Ventral	Dorsal	Lithology
(GSC)						
?C-4007	Ell	F-G		1m		calc. sls
C-4016	Ell	F	1m	1i, 2em, 8m	1m	calc. sls
C-4019	Ell	F	1m	1m	1m	fine ss
C-4023	Ell	?Fps		2m	1m	calc. sls, skel. lmst
?C-4063	Ell	F1		1em		calc. sls
C-4081	Ell	F1	2m	4em, 4m	1em	fine lmst
C-6136	Ell	?	1m	1i, 2m		sls
C-47947	Ell	?F		2i, 3em, 4m	1em	skel. lmst
53929	Tat	Ft	1em	2i, 5em	1em	dark lmst
76029	Cam	Gc	1m	1m		green ss
58977	Ell	F1	1m	1i, 10em, 5m	1i, 1m	coarse skel. lmst

Description

External. Shells large for genus, elongate; maximum width placed in anterior third of length; hinge width 0.7 to 0.8 of maximum width, abruptly obtuse at 105 to 110 degrees. Ventral umbonal region highly convex, comprises 0.2 to 0.3 length of valve; interarea length about 0.3 of hinge width; interarea slopes at 140 degrees to commissure in mature shell; steep lateral flanks slope at 70 degrees to commissure near hinge. Deltidial plate covers much of delthyrium, angle 50 degrees, arched toward beak in GSC 35654 and 35655 from GSC locality C-4081. Dorsal valve moderately to gently convex, slightly wider than long.

Sulcus shallow with gently concave floor; sulcal angle 20 degrees at 10 mm from umbo, decreasing slightly as distance from umbo increases, to a minimum of 15 degrees at 60 mm. Most specimens have low median sulcal costa. Flanking costae start 5 to 15 mm from umbo and furcate progressively to produce normally three, to as many as seven costae on either side of sulcal midline at anterior margin. Fold distinct; very broad in shells from GSC localities 58977 and C-6136, higher in GSC 35645 from GSC locality C-4016, and GSC 35647 from GSC locality C-4019. Crest narrow, gently convex to flat in lateral profile; median groove for anterior half to two thirds of crest; flank of fold has a single costa, which diverges into three at about midlength.

Ventral valve bears five or six pairs of broad, low, rounded plicae; median two or, more commonly, three pairs have a low costa either side, starting between 10 and 25 mm from umbo and furcating into four or five costae anteriorly; costation varies in specimens from single collections. Interspaces usually wide, but may be narrow in some individuals within single collections. Dorsal valve has four or five pairs of plicae; median three pairs develop a low costa each side of midlength.

Ventral micro-ornament of three fine concentric lirae per mm, and four radial capillae per mm; with minute pustules.

Internal. Ventral muscle platform highly elevated; dental plates and adminicula buried in secondary thickening. Dorsal septum arises in front of cardinal process, is nearly a third of valve in length, is succeeded anteriorly by median groove in GSC 35665 and 35666, from GSC locality 58977, Ellesmere Island.

Dimensions

Spec.	Loc.	Width	Length	Dorsal length	Height	Hinge width	Umbonal angle
		(mm)					(degrees)
(GSC)	(GSC)						
35644	C-4016	50	53		26.5	39	100
35645	C-4016	41	49	36.5	30 B	33	
35646	C-4016	?39	+46		+20	?33	90
35647	C-4016	45		36.5	11.5	?40	
35648	C-4023	57	64		29	?39	
35649	C-4023	45		37	14	34	
35652	C-4081	54	53		22	44.5	105
35653	C-4081	51	60	50	39.5B	36	90
35654	C-4081	44	56		25.5	30	90
35655	C-4081	36	40		17	?29.5	80
30802	C-6136	52.0	+61.5	44.5	23	39.5	
30803	C-6136	60	69	48	25.5B		
35682	C-6136	50	56		22	47	105
35656	58977	39	54.5		29	?27	80
35657	58977	+26	+24		+12	22	90
35658	58977	+47	+48		+25	23	100
35659	58977	27	22		9	23	110
35660	58977	31	28		13	26.5	100
35661	58977	36	+38		23	34	85
35662	58977	45	44		25	31	80
35663	58977	32.5	39		19.9	27	90
35664	58977	+36	+37.5		+21	32.5	90
35665	58977	30		21	7	25	
27040	53929	29	29	25.5	26	28	85
35716	53929	32.5	34		+15	24.5	100
35691	53929	+37	+32.5		14.5	33	100
35651	76029	44	52	22	27	34	85
35718	C-47947	20.5	22		10	15.5	85
35719	C-47947	+30	36		16.5	22.5	80
35720	C-47947	33.5	43		20.5	?26.5	?80
35721	C-47947	+29	+27		13.5	24	

Variation. Specimens from the Tahkandit Formation, Tatonduk River at GSC locality 53929 are small and comparatively transverse, with simple plicae over the posterior 25 to 35 mm of shell length. They have a median sulcal costa. The fold is typical.

Specimens from GSC locality C-47947 (Bjorne Peninsula, Ellesmere Island) are elongate to equidimensional in outline, bearing strong plicae and low costae (Pl. 4, fig. 15), rather like specimens from GSC locality 57121 of the *Antiquatonia* Zone (Fa) in the Tatonduk River area, but they are more elongate than most other specimens. GSC 35721 has a narrow dorsal fold with a shallow sulcus anteriorly and the material is moderately close to *Spririferella keilhavii* (von Buch) from the Kungurian and Kazanian beds of the Arctic.

Resemblances. This species is distinguished primarily by the low dorsal fold, which is generally smooth or has a very shallow groove posteriorly, and a broad shallow groove in front, with many costae. The shape varies considerably from transverse to elongated and costation also varies. In essential details the Canadian specimens appear to belong to *S. keilhavii*, first described by von Buch (1846), though it is not easy to be certain because, as outlined by Dunbar (1955), von Buch reconstructed his figures from several specimens. *Spirifer wilczecki* Toula is well figured and the Canadian shells are definitely conspecific with this form, but they apparently fall in synonymy with *S. keilhavii* as generally understood. Another shell named *Spirifer draschei* Toula is figured as ventral valves, making its identity hard to ascertain, but it seems likely to be conspecific with *S. keilhavii*. Where ventral valves only are described, such as *Spiriferella draschei* and *S. keilhavii* recorded from transverse ventral valves, from the *Spirifer* Limestone of Bjørnøya, ascribed by Gobbett (1964, Pl. 20, figs. 8 - 10) to *S. keilhavii*, more closely resemble *S. loveni* in outline and costation, but again this is not certain.

Ventral valves from the Nosoni Formation of northern California figured by Coogan (1960, Pl. 27, figs. 1, 2, 5) as *Spiriferella polaris* (Wiman) might prove to be *S. loveni*, but the dorsal valve needs to be studied for confirmation. The fauna is of Nevolin age. Small specimens of *Spiriferella loveni* look somewhat like *S. polaris* (Wiman) but, unlike *polaris*, the dorsal fold has a deep median groove commencing at the umbo. As a rule, the outline of mature shells is more transverse, posterior walls are more concave in outline, costae over the plicae are more numerous, and ventral muscle platform is higher.

Spiriferella saranae lita Frederiks (1924b, Pl. 1, figs. 16 - 27), from lower mid-Permian beds of Ussuriland, is allied, though it is narrow in shape and has a fairly narrow dorsal fold and narrow median dorsal groove of varying definition. It is especially close to shells from the Tatonduk River valley.

Other specimens ascribed to *S. lita* are indeterminate in the absence of or failure to figure the dorsal valve (Frederiks, 1934, Pl. 3, figs. 24, 25a, b; 1936, Pl. 1, fig. 13; Zavodowsky, 1970, Pl. 50, fig. 5), or possibly belong to *S. polaris* (Stepanov, 1937a, Pl. 7, fig. 7).

It appears possible that *Spiriferella loveni* will prove to be identical with *Spiriferina hoeferiana* Toula (1874, p. 135, Pl. 1, fig. 1a - d) from Spitzbergen. A similar form from Abrosimov Bay in Novaya Zemlya was identified with this species by Likharev and Einor (1939, p. 221, Pl. 28, fig. 5). Although, with Branson (1948, p. 511), these authors ascribed the species *hoeferiana* to the Spiriferinidae, members of this family do not normally have a sulcate dorsal fold, though examples with it are known. Frederiks (1936, p. 99), in describing a fauna from Novaya Zemlya, assigned the species to *Spiriferella*, but his illustrated specimen (Frederiks, 1936, Pl. 1, figs. 10 - 12b) apparently lacks a cleft in the dorsal fold and so looks closer to *Spiriferella polaris*. The figured specimen of *hoeferiana* is perhaps more transverse and alate than *Spiriferella loveni* (Diener). Toula (1874), identifying the genus from shape, made no mention of the degree of punctation in the shell.

Spiriferella arctica (Haughton 1858)

Plate 8, figure 8

1858 *Spirifer arctica* Haughton, p. 243, Pl. 9, fig. 1

Lectotype (here designated). Specimen from Bathurst Island figured by Haughton (1858, Pl. 9, fig. 1), kept in M'Clintock's collection, 95:1905/3, National Museum, Dublin, Eire.

Material and localities. A ventral valve from Bathurst Island, north coast, Cape Lady Franklin(?), latitude 76°40'N, longitude 98°45'W; also recorded from Hillock Point, Melville Island, latitude 76°N, longitude 111°45'W.

Discussion. The type is preserved as the posterior part of a ventral valve, which has incurved umbo, wide hinge, high interarea and well formed sulcus bearing two moderately strong subplicae. There are five pairs of plicae with round crests and interspaces of comparable width. Traces of low anterior costae are seen on the two inner pairs of plicae. The shell most closely approaches *Spiriferella loveni* (Diener) in appearance, but the absence of the critical dorsal valve makes identification impossible. Unless further topotype material can be found, the species presumably will have to lapse.

Dimensions. Width +35.5 mm, length +30 mm, hinge length +34.5 mm, height +16 mm, umbonal angle 90 degrees, sulcal angle 20 degrees.

Age and formation. W.W. Nassichuk, Institute of Sedimentary and Petroleum Geology, Calgary, has most kindly provided the following comments on the localities and formations from which *Spiriferella arctica* specimens were collected:

> The locality at Hillock Point, northern Melville Island is in the Trold Fiord Formation. The formation is about 100 feet thick, rests on Devonian rocks and is overlain by the Triassic Bjorne Formation. As far as the Bathurst Island locality is concerned, no one can say for sure what the formation is, because it appears that nobody has seen Permian rocks there since 1855. It is very near the southern edge of the basin and the locality is probably in a small erosional remnant. Belcher Channel Formation is likely since it crops out not too far away on Helena Island.

It appears, therefore, that *Spiriferella arctica* came from a formation older than deposits found elsewhere containing *S. loveni*. However, the specimen does not resemble *S. saranae*, *S. pseudosaranae* or *S. salteri*, species which characterize Early Permian faunas correlative with those of the Belcher Channel Formation.

Spiriferella keilhavii (von Buch 1846)

Plate 4, figure 15; Plate 6, figures 3 - 14;
Figures 16e, g, h, i, 19

1846 *Spirifer keilhavii* von Buch, p. 74, Pl. 1, fig. 2a, b
?1873 *Spirifer* sp. indet. Toula, p. 273, Pl. 2, figs. 1, 2
1873 *Spirifer wilczecki* Toula, p. 271, Pl. 1, fig. 3a, b
1875 *Spirifer draschei* Toula, p. 239, Pl. 7, fig. 4a - c
1914 *Spiriferina draschei* (Toula), Wiman, p. 38, Pl. 3, figs. 2 - 26
1916 *Spiriferella parryana* (Toula), Chernyshev and Stepanov, p. 54, Pl. 11, fig. 4a - c
1916 *Spiriferella draschei* (Toula), Chernyshev and Stepanov, p. 54, Pl. 9, fig. 2
1931 *Spiriferella keilhavii* (von Buch), Frebold, p. 28, Pl. 5, figs. 7 - 9
1937a *Spiriferella draschei* Toula, Stepanov, p. 149, 180, Pl. 8, fig. 10 (fig. 9 indet.)
1938 *Spiriferella parryana* (Toula), Frebold, in Frebold and Noe-Nygaard, p. 23, Pl. 1, figs. 10, 11
1955 *Spiriferella keilhavii* (von Buch) Dunbar, p. 139, Pl. 25, figs. 1 - 9, Pl. 26, figs. 1 - 11, Pl. 27, figs. 1 - 9, 12, not 10, 11, 13, 14 = *parryana (loveni)*
1964 *Spiriferella draschei* (Toula), Gobbett, p. 154, Pl. 20, fig. 7
1968 *Spiriferella rajah* (not Salter) subsp. B, Nelson and Johnson, p. 736, Pl. 95, figs. 1 - 4, Pl. 96, figs. 1 - 3, and 11
1968 *Spiriferella rajah* (not Salter) subsp. A, Nelson and Johnson, p. 731, Pl. 94, figs. 1 - 15, Pl. 96, fig. 10
1971 *Spiriferella draschei* (Toula), Brabb and Grant, p. 17, Pl. 2, figs. 26 - 28, 34, 35
1971 *Spiriferella* aff. *keilhavii* (von Buch), Bamber and Waterhouse, p. 165, Pl. 20, fig. 7
1971 *Spiriferella* sp. Bamber and Waterhouse, p. 174, Pl. 19, fig. 12

Syntypes. Figure by von Buch (1846, Pl. 1, fig. 2a, b) is a composite drawing, said by Dunbar (1955) to be atypical of

Material and localities

Loc.	Valves: Both	Ventral	Dorsal
(GSC)			
C-4068		1m	
C-4069	1i	3j, 2i, 2em, 3m	1em, 3m
C-4070		4i, 2em, 3m	1em
C-4071		2em, 2m	1m
C-4074	1i, 1em, 1m	1j, 2i	1i
C-4095		2m	1m

Area: Ellesmere Island.
Brachiopod zone: Gc.

Lithology. Fine black limestone or calcareous siltstone.

Description

External. Medium large, weakly transverse shells with maximum width placed at hinge or just in front at midlength; dorsal valve two-thirds length of ventral valve; ventral umbo blunt, slender, not strongly incurved. Interarea relatively flat, delthyrium at close to 50 degrees, closed by convex plate in holotype. Cardinal angles usually bluntly obtuse, from 80 to 140 degrees. Dorsal valve little inflated, laterally very thin.

Sulcus broad with U-shaped cross-section, sulcal angle about 20 degrees, sulcal floor with two low, weak costae; each bordering plication has a faint broad costa starting 25 to 30 mm from umbo. Fold low, at 27-degree angle, with a deep median groove commencing at hinge. Ventral valve has five---or rarely, six---pairs of plicae; dorsal valve has four or five pairs of high, rounded simple plicae with broad deep interspaces. Micro-ornament not preserved.

Internal. Ventral umbonal cavity filled with secondary thickening. Dental plates converge at 90 degrees; adminicula diverge at 90 degrees. Muscle platform only slightly elevated anteriorly, tapering, with no anterior ridge; no groove or ridge on posterior wall. Adductors long, narrow, raised, with a weak myophragm; diductors weakly striated longitudinally.

Cardinal process small, laminated; socket plates subhorizontal; crural plates anteroventrally inclined; dorsal adductors short, rounded, smooth. Median septum not developed in holotype GSC 30798 (at early maturity), from GSC locality C-4074, Ellesmere Island.

Dimensions

Spec.	Loc.	Width	Length	Dorsal length	Height	Hinge width	Umbonal angle
		(mm)					(degrees)
(GSC)	(GSC)						
30800	C-4069	35		27.5	5.5	34	
30799	C-4074	59	+45.5	+30.5	28B	+49	85
30801	C-4095	?57	+50		?20	53.5	80

Resemblances. The broadly bifurcating fold of *Spiriferella leviplica* is not typical of *Spiriferella* and resembles the fold of *Timaniella*, but the strongly plicate shell and lack of strong alation show its alliance to *Spiriferella*. The new species resembles *Alispiriferella ordinaria* (Einor), a Sakmarian species, in muscle scars, shape and costation of sulcus, number of plicae and bifurcating fold.

Genus *Eridmatus* Branson 1966

Type species: *Spirifer (Trigonotreta) texanus* Meek 1876

Diagnosis. Distinguished from *Spiriferella* by deep sulcus, high fold and swollen lateral slopes with plicae and narrow interspaces.

Discussion. In proposing the genus *Eridmatus*, Branson (1966) was unaware of its close relationship to *Spiriferella*. The differences between the two appear to be of minor significance but, as the name is available, it serves to distinguish a minor and apparently less successful lineage from the main branch referred to *Spiriferella*. However, it may be that the separation is indefensible. Cooper and Grant (1976) defended the validity of the genus by enumerating trivial differences that probably are irrelevant, especially as they based comparisons with *Spiriferella* from Texas rather than with the type species. They did, however, make the possibly important observation that surface pustules were sparse, but they gave no quantitative analysis nor figures to substantiate the statement. Certainly, to judge from what is so far known about genus *Eridmatus*, it appears to be much closer to *Spiriferella* than many other species that have been regarded as congeneric with *saranae*, and indeed it appears to fall very close to the *Spiriferella supplanta* lineage. For assigning species to *Eridmatus*, we rely on shape, entailing deep narrow sulcus, relatively high fold, swollen lateral slopes on the ventral valve, plicae and rather narrow interspaces. The actual details and variability of surface pustules remain to be ascertained.

Eridmatus petita n. sp.

Plate 2, figures 1 - 6; Figure 11g, h

Holotype. GSC 35502, JBW locality 19 (Pl. 2, fig. 2; Fig. 11h)

Paratopotypes. GSC 35498, 35499, 35501, 35503; JBW locality 19

Diagnosis. Closely costate, small to medium *Spiriferella* with strong plicae, well rounded outline and prominent ventral umbo.

Material and localities

Loc.	Area	Brach. zone	Valves: Ventral	Dorsal	Lithology
(JBW)					
19	Ett	Eka	2j, 25i, 2em		calc. sls
27	Ett	Eta	2j, 6i, 3em		carb.
127	Ett	Eta	1m		carb.
135	Ett	Eta		1m	sls
993	Ett	Eka	3m		carb.
994	Ett	Eka	2m		carb.
996	Ett	Eo	2m		carb.
(GSC)					
56920	Tat	Eta	2i		sls
55136	Bell	Eta	2m		calc. ss
53995	Ett	?E or D	1m		silty black lmst

Description. Shell small, ventral umbo prominent, moderately incurved, angle close to 80 degrees, posterior walls high; concave in outline, hinge wide, occasionally at maximum width; shell outline well rounded in front, maximum width generally just in front of midlength, occasionally at hinge. Ventral interarea high, strongly incurved under beak, delthyrial angle close to 50 degrees, deltidium not exposed. Cardinal extremities generally bluntly obtuse, at 110 degrees, but ventral valve from JBW locality 127 has alate extremities at 60 degrees, with the hinge at maximum width. Dorsal interarea very low. Sulcus has concave floor, and angle of 15 to 20 degrees, generally 16 or 17 degrees, flaring very slightly in front, usually with median costa. Fold low, narrow, bearing slender groove for entire length. Four (rarely five) pairs of well defined plicae on ventral valve, with narrow interspaces. Costation varies: some shells develop costae early, some later, others not at all, even within one collection (e.g., JBW loc. 994, Ettrain Creek area). Plicae often have one costa along inner or sometimes outer flank and may develop more---four on the innermost pair, two or three on the next pairs. Costae are fine, and either even or variable in width. Dorsal valve has three or four pairs of plicae, and three costae on each flank of the fold. Micro-ornament is normal *Spiriferella* micro-ornament, but is too poorly preserved to be measured accurately.

Interior not known, apart from GSC 35501 from JBW locality 19, Ettrain Creek area, which shows dental plates converging at 75 degrees and a cross-section of the spires, with 14 turns.

Dimensions

Spec.	Loc.	Width	Length	Dorsal length	Height	Hinge width	Umbonal angle
				(mm)			(degrees)
(GSC)	(JBW)						
35497	994	+30	+28.5		+29.5	+13	85
35498	19	+11.7			+12.6	4.3	77
35499	19	15			12	5.5	75
35502	19	20.5	?18.5		21.5	12.2	80
35503	19	29			+25.5	+14.5	
35507	27	16	?11		15.5	6.7	?85
	(GSC)						
35512	56920	+9.5			?13	+7	70

Variation. Among material of the Ettrain Creek area, shells from JBW localities 19 and 994 vary in costation. Specimens from JBW locality 993 are large and have very sturdy costae. Ventral valves from GSC locality 56920, Tatonduk River, are elongate, with few costae, and generally have narrow umbones. A poorly preserved ventral valve from GSC locality 53995, Ettrain Creek area, from the upper part of the new formation, appears closer to this species than to *Spiriferella yukonensis* n. sp.

Resemblances. This species is close to *Eridmatus marathonensis* Cooper and Grant (1976, Pl. 626, figs. 10 - 20) from the *Uddenites* Shale Member of the Gaptank beds of west Texas. Its general appearance, cardinal extremities, sulcus and fold are similar, but it is smaller and has fewer costae as a rule, and apparently a slightly wider sulcus. The Texas shells also appear to be a little more elongate, and to have plicae less outwardly curving on the dorsal valve.

The type species of *Eridmatus, E. texanus* Meek from the mid-Pennsylvanian of United States, has a deeper sulcus and higher fold than this species; it also has maximum width placed anteriorly and coarse costae, as well as other differences.

Spiriferella asiatica Volgin (1959, Pl. 6, fig. 7; 1960, Pl. 15, fig. 3) from the Dastar horizon of south Fergana, USSR, is very close in the general appearance of the ventral valve. On the dorsal valve of *asiatica* the fold appears to be more rounded, with costae and no median groove other than an intercostal space if the figure is interpreted correctly, and the fold flares considerably near the anterior margin, as in *Eridmatus texanus. Spiriferella asiatica* is dated as Late Carboniferous, though accompanying supposed *Pseudofusulina* is regarded as typically Permian by North American experts. Accompanying brachiopods appear to be Late Carboniferous rather than Early Permian, but this is not certain.

The ventral valve from the lower Zilim Suite of the Bashkirian Urals, assigned to *Spiriferella praesaranae* Stepanov by Mironova (1967, Pl. 4, fig. 5), is somewhat similar to this species in size, shape and ornament, but subplicae are well developed along the inner side of the plicae bordering the sulcus. The dorsal valve is not figured. The age is Gshelian-Asselian. *Spiriferella turusica* Chernyak (in Ustritsky and Chernyak, 1963, Pl. 37, figs. 1 - 3), from the Turuzov faunas of Asselian age at Taimyr Peninsula, is strongly incurved and has alate wide hinge, simple plicae and a narrow fold grooved anteriorly.

Spiriferella altaica Besnosova (1968, Pl. 27, figs. 5 - 7), from the lower Asselian Kokpecten Suite of Kazakhstan, has a slender median groove arising at the dorsal umbo on the fold but, unlike *E. petita*, it has massive shoulders and very low ventral umbo. *Spiriferella mica* Barkhatova (1968, Pl. 46, fig. 2; 1970, Pl. 19, figs. 1 - 5, 8), from the mid-Asselian Nenetz beds of Timan, is similar to *S. altaica*, with concave posterior walls and long ventral umbo. But it cannot be assessed adequately because the dorsal valve was not figured.

This species differs from *Spiriferella yukonensis* n. sp. in its more pentagonal shape, narrow dorsal fold with very slender median slit, and tendency to be more costate. In its prominent ventral umbo, concave posterior walls and sturdy plicae, *Eridmatus petita* is close to *S. ploskajae* Zavodowsky (1970, Pl. 33, figs. 6 - 9) from the upper Asselian Paren Suite of northeastern Siberia. The Yukon specimens are more frequently costate and seem to have a slightly wider hinge, but the Siberian shells are broken laterally. The figured dorsal valve of *S. ploskajae* shows a narrow fold and a shallow groove, which commences in front of the umbo, unlike Canadian specimens.

Genus *Alispiriferella* n. gen.

Type species: *Spririferella ordinaria* Einor 1939

Diagnosis. Transverse alate Spiriferellinae, subrectangular in outline, with wide, well defined sulcus along crest of dorsal fold. Interior largely as in *Spiriferella*, with substantial secondary shell in ventral valve.

Discussion. This genus is represented by two species, *ordinaria* Einor and *gydanensis* Zavodowsky. They are very distinctive in shape, being transverse with alate cardinal extremities and sulcate dorsal fold, but they are not as extremely transverse as *Timaniella* and they retain a thick ventral valve as in *Spiriferella*. The species stand well apart from the *Spiriferella saranae-keilhavii-supplanta* plexus and from the rather similar lineage referred to *Eridmatus*. Their dorsal fold is similar to that of species such as *Spiriferella loveni* (Diener) and *S. leviplica* n. sp.; however, these two species may have diverged independently from the *Spiriferella keilhavii-rajah* lineage plexus, although further study may show this to be incorrect.

Alispiriferella ordinaria (Einor 1939)

Plate 2, figures 7 - 13; Figures 11i, j, 20

1939 *Spirifer (Spiriferella) keilhavii* var. *ordinaria* Einor, in Likharev and Einor, p. 140, Pl. 23, figs. 6, 7, Pl. 24, fig. 1

1939 *Spirifer (Spiriferella) keilhavii* var. *altisinuata* Einor, in Likharev and Einor, p. 142, Pl. 24, figs. 2, 3
1939 *Spirifer (Spiriferella) keilhavii sulcifer* not Shumard, Einor, in Likharev and Einor, p. 218, Pl. 24, fig. 4, ?not 5
1968 *Spiriferella ordinaria* (Einor), Nelson and Johnson, p. 738, Pl. 95, figs. 5, 6, Pl. 96, figs. 4 - 6, Textfigs. 3f, 10, 13a
1971 *Spiriferella ordinaria* (Einor), Waterhouse, in Bamber and Waterhouse, p. 148, 149, 156, 158, Pl. 15, figs. 10, 12 - 14

Holotype (by original designation). Specimen figured by Einor (in Likharev and Einor, 1939, Pl. 24, fig. 1); kept at Chernyshev Museum, VSEGEI, Leningrad.

Diagnosis. Shells slightly wider than long; cardinal extremities moderately alate, sulcus shallow, broadening slightly and deepening abruptly after midlength, bearing two prominent sulcal costae; fold low, crest wide, bifurcates near umbo; four to five pairs of plicae on each valve, simple costae well developed anteriorly; general muscle platform moderately raised.

Material and localities

Loc.	Area	Brach. zone	Valves Both	Valves Ventral	Lithology
(JBW)					
229	Peel	Ea	2m		sandy sls
(GSC)					
53714	Peel	Ey	3m		sls
53715	Peel	Ea	2m	4i, 6m or 1	sandy sls
55137	Jun	Eta	12m	2m	calc. sls
57273	Tat	Ey		2i, 1m	sls
57044	Tat	Ea or Eta		3em	sls

Description

External. Shells of moderate size, slightly wider than long, maximum width variably placed between hinge and midlength. Lateral flanks of ventral valve gently concave in outline posterolaterally, rounded anteriorly, and making an angle of 35 to 40 degrees with commissure. Dorsal valve gently convex. Length of ventral interarea 0. 17 the width. Dorsal valve length 0.75 to 0.8 length of ventral valve. Sulcus flat-floored, sulcal angle 20 degrees for posterior 0.5 to 0.6 of length, then angle increases slightly and sulcus deepens to a broad V with anterior tongue protruding dorsally. Sulcus has one or two pairs of costae, but no median costa. Fold low, broad, steep-sided anteriorly; crest almost flat anteriorly in lateral profile, with a deep, wide, flat-floored median groove for almost entire length. Each flank of fold has a single costa on its anterior half, and another pair occurs within the sulcus of GSC 35513 from JBW locality 229.

Both valves have four or five pairs of high, sharp or broad-crested plicae. Ventral plicae initially simple, with concave interspaces; median two pairs on some specimens develop two or three costae in anterior half.

Dorsal plicae widely spaced, with regular frequency. All may remain simple, or three inner pairs may divide into two equal or three unequal costae over anterior half to two thirds of valve.

Dorsal micro-ornament of faint concentric and radial lirae, about five per mm in either direction; small pustules in quincunx formed from about three concentric lirae.

Internal. Ventral interior of worn internal mould GSC 26962, from Peel River at GSC locality 53715 (Ea) (see Waterhouse and Bamber, 1971, Pl. 15, fig. 17), 30 mm long, 39 mm wide, has a muscle platform 7 mm wide, 11 mm long; roughly rectangular in outline, has slightly extended, rounded anterior margin, surrounded by a raised border. Adminicula short, adductors long, narrow, total width 2.5 mm, diductors longitudinally striated, about three per mm. Another specimen, GSC 35514 from GSC locality 53715, Peel River area, has buried adminicula and no myophragm.

Dorsal interior poorly exposed. Septum long in GSC 35513 from JBW locality 229, Peel River area, extending forward from base of cardinal process. Serial section shows socket and crural plates, with about 14 turns in laterally directed spire.

Dimensions

Spec.	Loc.	Width	Ventral length	Dorsal length	Height Both	Height Ventral	Hinge width	Umbonal angle
		(mm)						(degrees)
(GSC)	(GSC)							
26960	53714	+39.8	38.4	28.0	24.7	17.6	+34.8	
30747	53714	+37.8	32.8	26.4	23.5	16.6	+32	
30748	53714	+38	-	-	23.2	16.6	+35.5	
26962	53715	39.5	31	25	24.0	16.5	36	-
30749*	55137	+30	35.6	+27.5	24.0	17.7	+27	75
30750	55137	41.6	34.8	+27.8	23.0	14.2	40.6	?70
30751	55137	+36.7	35.4	28.2	25.2	18.1	+34.2	70
30752	55137	-	40.3	19.9	26.9	20.1	37.2	?90
30753	55137	35.0	34.0	26.9	23.2	17.2	31.3	65
30754	55137	+38.7	35.8	27.2	23.3	17.5	+32.3	-

* Compressed laterally.

Discussion. Nelson and Johnson (1968) reported one specimen of *Spiriferella ordinaria* (Einor), from their west Mount Burgess section, associated with *S. keilhavii* (von Buch) and *S. rajah* subsp. B (not Salter). This specimen of *S. ordinaria* is not figured. The association seems too young for *S. ordinaria* and it is possible that they have misidentified a transverse specimen of *S. keilhavii* (von Buch) or *S. loveni* (Diener).

Alispiriferella ordinaria (Einor) is distinguished from *Spiriferella loveni* (Diener), from the Kungurian to Kazanian faunas of Spitzbergen, Siberia and Yukon, by its more transverse outline, less inflated ventral umbo, nonelevated muscle platform, and broader, less costate sulcus. The sulcal angle in this species tends to increase slightly anteriorly, whereas the angle in *S. loveni* remains constant or may decrease. *Spiriferella interplicatus karmukalensis* Einor (in Likharev and Einor, 1939, Pl. 18, fig. 4a, b) has two sturdy sulcal costae and may be conspecific. It comes from beds of uncertain age in Novaya Zemlya.

Alispiriferella gydanensis (Zavodowsky 1968)

Plate 7, figures 1 - 4

1968 *Spiriferella gydanensis* Zavodowsky, p. 159, Pl. 46, fig.1
1970 *Spiriferella gydanensis* Zavodowsky, p. 162, Pl. 75, figs. 1a, b, 5a, b, Pl. 78, fig. 3

Holotype (by original designation). Specimen figured by Zavodowsky (1968, Pl. 46, fig. 1; 1970, Pl. 75, fig. 1); kept at Chernyshev Museum, VSEGEI, Leningrad

Diagnosis. Equidimensional shells with alate extremities, feebly costate ventral plicae, noncostate dorsal plicae, fold with broad median sulcus and no costae.

Material and localities

Loc.	Area	Brach. zone	Valves Both	Ventral	Dorsal	Lithology
(GSC)						
58968	Ell	Fn	8m	4em, 3m		calc. ss
58973	Ell	Fn	1m			fine ss
C-10908	Yuk	Fn?	1i, 4m	2j, 3i, 7em, 7m	2m	sls, fine ss
C-3995	Ell	Gc			1i	green calc. sls

Description. Shells of moderate size, transverse, with prominent ventral umbones, only slightly incurved over very high ventral interarea, posterior walls concave in outline; cardinal extremities alate or obtuse at 60 to 100 degrees. Dorsal valve with low umbo and very low cardinal interarea. Ventral sulcus has angle of 20 degrees, is broad, bearing two costae on the floor; dorsal fold broad, with wide shallow median sulcus, without costae on the flanks. Plicae number four pairs on ventral valve, three pairs on dorsal valve, inner two ventral pairs sometimes with one costa anteriorly, dorsal plicae not costate.

Dimensions

Spec.	Width	Ventral length	Dorsal length	Height, both	Hinge width	Umbonal angle
			(mm)			(degrees)
(GSC)						
35728	+38.5	30	22	16	32	103
35729	37	33	26	19.5	35	100
35730	42	31	25	22.5	42	100
35731	+41	36.5	24.5	22		110

All from GSC loc. 58668.

Resemblances. This species is identical in shape and ornament with *Alispiriferella gydanensis* (Zavodowsky) from the Omolon Horizon of Kazanian age, in the Kolyma River region, northeastern Siberia. Possibly the Canadian material is more alate, but variation in alation cannot be assessed from the few specimens figured from Siberia. Material from Spitzbergen figured by Miloradovich (1936, Pl. 1, figs. 1 - 3, Pl. 2, figs. 1, 2, Pl. 4, figs. 1 - 9) may by conspecific since the dorsal valve seems to have a similar shape and fold. Miloradovich (1936) ascribed this material to *Spiriferella parryana* (Toula) (=*loveni* Diener), but Toula's type material has a more costate dorsal fold and less alate shape. Other Spitzbergen shells called *Spiriferella keilhavii keilhavii* and *S. keilhavii parryana* possibly belong to *Alispiriferella gydanensis* (Stepanov, 1937a, Pl. 7, figs. 9 - 11), judged from inspection at the Chernyshev Museum, Leningrad.

Genus *Timaniella* Barkhatova 1968

Type species: *Timaniella festa* Barkhatova 1968

Diagnosis. Transverse, gently to moderately convex shells, often strongly alate; both valves with six to eight pairs of simple or weakly costate plicae; sulcus shallow; fold often cleft medianly; micro-ornament of pustules and fine mesh-work of radial and concentric lines. Ventral valve has dental and adminicular plates, long narrow adductors and striated diductors; dorsal valve has crural and socket plates, laminated cardinal process, rounded adductors.

Timaniella differs from *Alispiriferella* in its more transverse shape, less elevated muscle field and smaller, less thickened umbonal region. General shape and sulcate fold show that the two were closely related. The fine radial and concentric lines and pustules in the micro-ornament indicate a close relationship to other Spiriferellinae.

Timaniella harkeri Waterhouse 1971

Plate 8, figures 9 - 18; Figure 21

1925 *Spirifer vercherei* (not Waagen) Frederiks, p. 25, Pl. 3, figs. 108 - 110

1960 *Pterospirifer* sp. A Harker and Thorsteinsson, p. 69, Pl. 21, figs. 1 - 14

1971 *Timaniella harkeri* Waterhouse, in Bamber and Waterhouse, p. 220, Pl. 26, figs. 10 - 21

Holotype (by original designation). GSC 26427, GSC locality 52705; figured by Bamber and Waterhouse (1971, Pl. 26, figs. 14, 22) from Permian sandstone unit, northern Richardson Mountains

Diagnosis. Shells transverse; ventral valve moderately convex, dorsal valve gently convex, maximum width at or near hinge; ventral interarea broad, short, striated vertically; delthyrium with apical angle of 70 degrees; sulcus weakly costate, sulcal angle 18 to 20 degrees; fold low, crest deeply cleft, diverging 7 to 10 degrees. Each valve has four to six pairs of plicae, faint laterally, with one, two or more broad, low costae. Ventral interior with short dental plates and adminicula; adductors long, narrow, impressed, diductors long, semielliptical, longitudinally striated. Dorsal valve with small laminated cardinal process, low crural plates and subhorizontal socket plates; adductors smooth and oval.

Material and localities

Loc.	Area	Brach. zone	Valves Both	Ventral	Dorsal	Lithology
(GSC)						
26406	Dev	Fn	38i, 89m	13i, 7m		fine ss
52705	Whi	Fl	1i, 8em	4em, 2m	1i, 1em, 1m	sls
58973	Ell	Fn	1m			fine ss
C-4016	Ell	F	1m	2m		med. calc. ss
C-4019	Ell	F		1m		fine ss
C-4023	Ell	F		1i, 1em, 4m		calc. ss
C-4080	Ell	Fps	3m		1em	sls
C-4081	Ell	Fl		1m		lmst
C-10904	Yuk	F	1m			sls
C-11868	Yuk	F	1em, 8m	1i, 53m, 15m	2em, 6m	med. ss

Discussion. Specimens from the Cache Creek Group at Kamloops, British Columbia, described by Crockford and Warren (1935) as *Spiriferella* sp., appear from their transverse outline and sulcate fold to be related possibly to *Timaniella harkeri*. They were examined briefly at the Department of Geology, University of Alberta, Edmonton, but need further study for full assessment of affinities. Also, specimens assigned by Yanagida (1963) to *Spiriferella keilhavii* (not von Buch) from the Mizukoshi Formation of central Japan include transverse forms with wide dorsal sulcus in the dorsal fold (ibid., Pl. 10, figs. 3c, 5), although severe distortion prevents certain identification.

Timaniella festa Barkhatova, inspected at the Chernyshev Museum of Leningrad, has a deep, wide dorsal cleft, not as wide as that of *harkeri*. Micro-ornament is poorly preserved.

Specimens figured from Spitzbergen by Stepanov (1937a) as *Spirifer moosakhailensis* Davidson (ibid., Pl. 7, fig. 2) and *Spiriferella keilhavii wilczeki* (ibid., Pl. 7, fig. 8) are transverse spiriferellin specimens likely to belong to *Timaniella*, but their specific affinities are not certain.

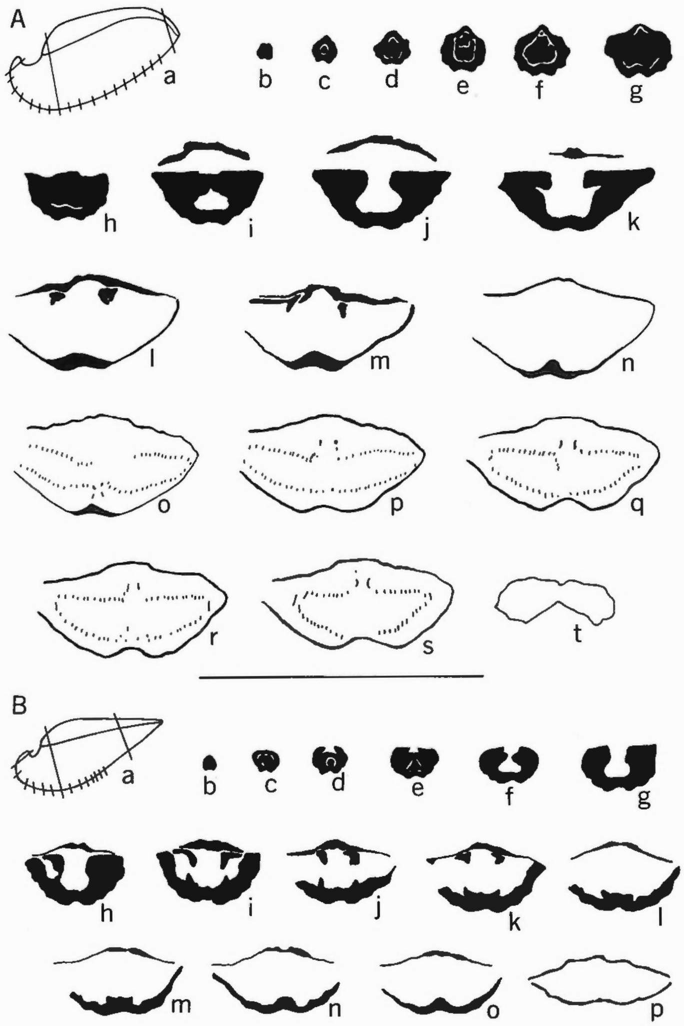

Figure 21. Timaniella harkeri *Waterhouse, serial section: (A) GSC 30806, GSC loc. 26406, Assistance Formation, Devon Island; (B) GSC 30807, same locality. Sequence from umbo to anterior margin. Approx.* x75.

Genus *Elivina* Frederiks 1924

Type species: *Spirifer tibetana* Diener 1897

Diagnosis. Shells often triangular in shape, having extended ventral umbo and short hinge, plicate and costate as in *Spiriferella*, but micro-ornament distinguished by predominance of concentric lirae, with pustules variable in development, often absent. Interior as in *Spiriferella*, secondary thickening in ventral valve possibly light.

Discussion. *Dienerina* Ozaki 1931 was proposed with the same type species. Pitrat (1965, p. H709), like many other authors, has synonymized *Elivina* Frederiks with *Spiriferella*. Examination of the type material by J.B. Waterhouse in August 1973, at the Geological Survey of India, Calcutta, revealed faint concentric ornament, with no visible pustules, but the surface is not well preserved. The specimen GSI 6112, figured by Diener (1897, Pl. 6, fig. 1a-e), was designated lectotype by Waterhouse (1966, p. 53). Zewan specimens from Mandakpal, Kashmir, described by Diener (1915, Pl. 9, figs. 5, 6) as *Spiriferella rajah* (Salter), have well preserved micro-ornament of concentric lamellae without pustules, as noted by Diener (ibid., p. 86). The hinge is wider than is usual for *Elivina tibetana*, but the material conceivably belongs to a species of *Elivina*, though this is rather dubious. More transverse specimens, which were recorded as *tibetana* from Nepal by Waterhouse (1966), are reassessed as belonging to *Spiriferella*. Waterhouse (1966) noted that some of these specimens seemed to have a pustular surface, possibly due to weathering rather than original.

Well preserved material that agrees in shape with *Elivina* has been examined at the Department of Geology, University of Melbourne, through the courtesy of N. Archbold. It comes from the Callytharra Limestone of Western Australia. The material suggests that pustules develop variably on different specimens, and that concentric ornament generally predominates.

Cooper and Grant (1976, p. 2241) have provided a somewhat indecisive discussion of the genus, including a description rather than a diagnosis of its attributes. They have provided an interesting comment on the unusual nature of its "low fastigium", but unfortunately this and other observations are based principally on *Elivina detecta* Cooper and Grant, a most unusual *Elivina*, if indeed it is congeneric, possessing costate ornament and allegedly no plicae. Moreover, they treated the *Elivina* specimens of Chernyshev (1902) as though they represented the type species, but Chernyshev's material is Early Permian, from the Urals, and not conspecific with the type species, which is of late Middle Permian age from the Himalayas.

Canadian occurrences of the genus *Elivina* are somewhat doubtful, as only two somewhat decorticated specimens are known. They seem to lack pustules, but are not well preserved. However, the shape is typical and the specimens may be assigned tentatively to the genus. Specifically they are most distinctive.

Elivina tschernyschewi n. sp.

Holotype (here designated). *Spiriferella tibetana* not Diener, Chernyshev 1902, Plate 17, figure 3; kept at Chernyshev Museum, VSEGEI, Leningrad

Discussion. Ivanova (in Sarytcheva, 1960) allowed the validity of *Elivina* Frederiks but cited *Spirifer tibetana* Chernyshev not Diener as type; it seems probable that Frederiks (1924a) based the genus on specimens identified by Chernyshev, rather than Diener's original material. However, the species cannot be attributed to Chernyshev without recourse to the Commission on Zoological Nomenclature to appeal for suspension of the rules, and this does not seem necessary.

The Russian shells are small and triangular, and resemble *Spiriferella* from the *Schwagerina* beds of the Urals. They were referred to *Spirifer tibetana* Diener by Chernyshev (1902), a somewhat unlikely reference, as Diener's species is much younger and less inflated, with more concave posterior walls and shallower median groove on the fold. The Russian species, apparently like *tibetana*, possibly lacks pustules (Frederiks, 1924a; Ivanova, in Sarytcheva, 1960, p. 270), as we have confirmed by examination; but the shell surface is not necessarily well preserved. It is here named *Elivina tschernyschewi* n. sp.

Elivina cordiformis n. sp.

Plate 8, figures 1 - 7; Figure 16j

1971 *Spiriferella* sp. Bamber and Waterhouse, p. 178, Pl. 21, fig. 16

Etymology. (Latin) *cordiformis*, heart-shaped

Holotype. GSC 27034 (Pl. 8, figs. 1 - 5)

Paratype. GSC 30797 (Pl. 8, figs. 6, 7)

Diagnosis. Highly inflated shells of small to moderate size; cardioid outline; hinge less than half maximum width; interarea small, anterior of sulcus sharply geniculate; each valve has five pairs of finely costate plicae; sulcus highly costate.

Material and locality. Two specimens with valves conjoined, from GSC locality 53838, near Symmetry Mountain, northern Richardson Mountains.

Description. Shell slightly wider than long, highly inflated, cardioid-shaped; maximum width in anterior third of shell length; hinge less than half maximum width; ventral interarea small, umbo small, sharply incurved; sulcus anteriorly prolonged. Ventral lateral flanks curve inward behind hinge, continuing smoothly onto dorsal flanks; angle with commissure at anterior margin 40 degrees ventrally, 45 degrees dorsally.

Sulcus starts at umbo, and is broad and deep; floor V-shaped, with a fairly constant cross-sectional angle of 120 degrees. A median costa and one nearby on either side occur 10 mm from umbo; median costa does not bifurcate, other costae fork progressively, giving 15 low sulcal costae at anterior margin. Fold high, delineated by a pair of narrow interspaces diverging at 50 degrees; crest moderately convex in lateral profile, divided by a narrow median groove; flanks of fold have a single costa, which divides into three at midlength.

Both valves have five pairs of plicae, well defined near umbo and becoming less distinct anteriorly; first three pairs subdivide into at least three costae; subsequent plicae also subdivide, but become indistinguishable at lateral margins. Excluding fold and sulcus, 14 costae discernible on each side of shell at commissure.

Faint growth lines on both valves, but micro-ornament not otherwise preserved. Interior not known.

Dimensions

Spec.	Loc.	Width	Length		Height, both	Hinge width
			Ventral	Dorsal		
(GSC)	(GSC)		(mm)			
27034	53838	40.7	39.0	+31.5	32.4	19
30797	53838	30.6	+25.0	+21.5	21.5	15

Resemblances. The inflated cardioid shape and narrow hinge of this species are diagnostic. The geniculation may be exaggerated by deformation, but although the holotype is chipped dorsally it does not appear to have been badly deformed. The paratype is broken anteriorly.

The species is distinguished from *Elivina tschernyschewi* n. sp. from the Lower Permian of the Urals by its more triangular shape, deeper sulcus, more costate fold without the well defined median groove. *Elivina tibetana* Diener (1897) is also less triangular in outline, and has a more extended less incurved ventral umbo and less costate plicae. It occurs widely in Punjabian faunas of the Himalayas and Timor.

Genus *Plicatospiriferella* n. gen.

Type species: *Plicatospiriferella canadensis* n. sp.

Diagnosis. Small Spiriferellinae distinguished by many plicae over both valves, few costae. Hinge alate, fold and sulcus moderately well defined, fold crest narrow and rounded or with shallow median groove. Pustules small, slightly transverse.

Discussion. This species, together with *Spiriferella gjeliensis* Stepanov and *S. praesaranae*, if this is to be distinguished from *gjeliensis*, is distinguished from *Spiriferella* by its numerous plicae with few or no costae. In the alate hinge, the specimens approach those of *Eridmatus*, but *Eridmatus* is more elongate and has the same number of plicae as in *Spiriferella*.

Surface ornament is shown for *praesaranae* by Stepanov (1948, Pl. 10, fig. 7b). The pustules are rather transverse. The crest of the fold varies, but generally has a low median groove at least anteriorly, and the groove flares widely in one shell of *praesaranae* figured by Stepanov (1948, Pl. 10, fig. 8).

Spiriferella turusica Chernyak (in Ustritsky and Chernyak, 1963) from the Turuzov beds of Taimyr Peninsula, may be related, but it is poorly known.

Plicatospiriferella canadensis n. sp.

Plate 1, figures 7 - 10; Figure 11a, b

Holotype (here designated). GSC 26855 (Pl. 1, figs. 8 - 10)

Diagnosis. Shell subhexagonal in outline with prominent and little incurved ventral umbo, narrow sulcus; narrow, numerous plicae, and inner pairs high, the outer pairs narrow and low. Hinge wide, cardinal extremities slightly alate.

Material and localities. Single mature specimens with valves conjoined, from GSC localities 53726, 53725 and 53693, all from the Peel River; six ventral valves from GSC locality 57062, Tatonduk River; and a ventral valve from JBW locality 217, Peel River. All in silty carbonate.

Description. Shell small, ventral umbo with broad angle probably close to 90 degrees, and little incurved; posterior walls convex, sweeping abruptly out to cardinal extremities, which lie at maximum width of shell, feebly alate at about 60 degrees in GSC 26855. Dorsal umbo low, protruding a little beyond hinge, umbonal angle 150 degrees. Ventral cardinal area high, almost flat except under the beak, with delthyrium of 60 degrees, apparently closed by deltidium, though slightly obscured by matrix. Dorsal interarea very low. Sulcus deep, V-shaped in section, with angle of 20 degrees flaring to 23 degrees anteriorly; no median costa. Dorsal fold low, with rounded crest; no median groove in shell from GSC locality 53725 or 53726 (Peel River), narrow groove in shell from GSC locality 53693 (Peel River), flaring anteriorly, two costae on each flank. Plicae numerous, curving outward strongly, usually seven pairs on each valve, but ranging from six to eight. Inner three pairs moderately high on ventral valve, with interspaces of equal width. Innermost pair has three costae on sulcal flank, next pair has one costa. Innermost dorsal plicae bear one costa.

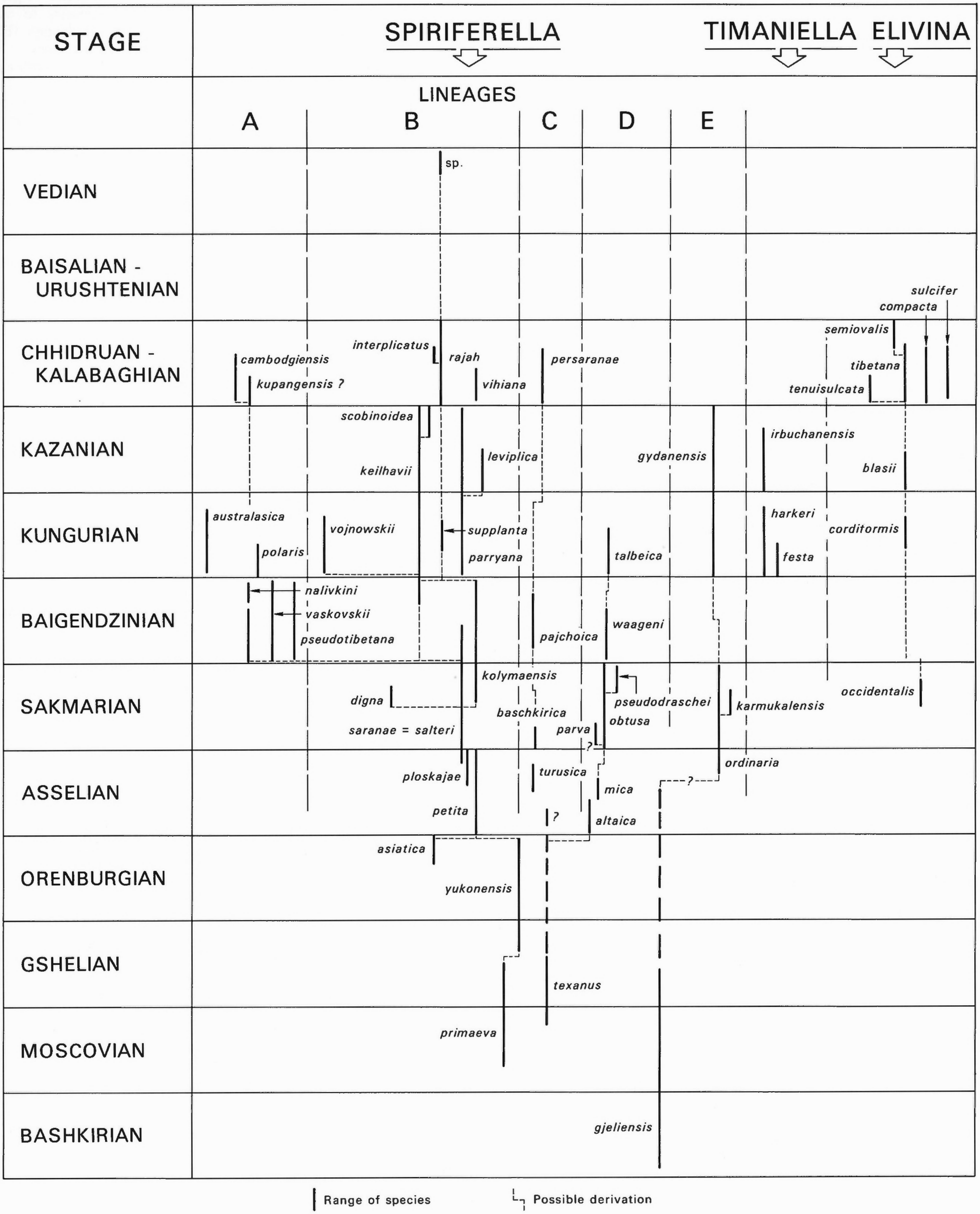

Figure 22. Evolutionary scheme for the subfamily Spiriferellinae.

The specimen GSC 35479 from JBW locality 217, Peel River, has similar umbo (angle 90°) and sulcus, four pairs of plicae and smooth broad outer flanks.

Dimensions

Spec.	Loc.	Width	Length	Height Both	Height Ventral	Height Dorsal
				(mm)		
(GSC)						
26855	GSC 53726	26	25	16.5	13.5	11
35479	JBW 217	31	+23		11.5	
35777	GSC 53693	28	26.5	18.5	15	13

Resemblances. These specimens are distinguished from *Spiriferella primaeva* n. sp. by their prolonged narrow, little-incurved ventral umbo, narrow sulcus, low rounded nongrooved fold, alate cardinal extremities and numerous narrow plicae. They are similar in shape, size and ornament to *Spiriferella gjeliensis* Stepanov 1939 from Gshelian beds at Gshel, Moscow, and also to *S. praesaranae* Stepanov 1948 from Ukla-kay, Bashkirian Urals, of Gshelian (sensu lato) age. The chief difference lies in the grooved fold of the Russian type specimen of *gjeliensis*, in which also the hinge is less alate than in the Canadian form. Menner et al. (1970) stated that *Spiriferella gjeliensis* Stepanov 1939 is conspecific with and senior synonym of *S. praesaranae* Stepanov 1948. The specimen they figure from the Upper Tiksin Suite, north Haraulakh (Menner et al., 1970, Pl. 11, figs. 3a, b, 4) has few and wide plicae, as in *Spiriferella primaeva* from Yukon Territory, and recalls a specimen illustrated as *gjeliensis* by Sarytcheva and Sokolskaya (1952, Pl. 263, fig. 355). A shell from the Bashkirian Urals in the Asselian-Gshelian Zilim Suite, figured as *S. praesaranae* by Mironova (1967, Pl. 4, fig. 5), also has few plicae, as in *S. primaeva* n. sp. Specimens figured as *praesaranae* in Stepanov (1976, Pl. 85, figs. 7, 8) have numerous plicae, as in *gjeliensis* from C2m C Kirov and Bolshekin horizons (=Moscovian) of the southern Urals.

DISTRIBUTION OF SPECIES OF SPIRIFERELLINAE: ENVIRONMENTAL CONTROLS

Yukon and Canadian Arctic Archipelago

Both *Spiriferella primaeva* n. sp. and *Plicatospiriferella canadensis* (Stepanov) (see Table 3) are found in silty carbonate of the Peel River area (Bamber and Waterhouse, 1971, p. 57). According to the reconstruction of facies by Bamber and Waterhouse (ibid., p. 101, Fig. 13), the two species inhabited inshore, fine clastic sediments during middle Desmoinesian time, rather than the skeletal limestone typical of the Ettrain Formation and found widely over the northern Yukon Territory, or offshore, more open water marine shale and carbonates now exposed in the Tatonduk River area. *Spiriferella primaeva* also is found rarely in carbonate at the top of the Ettrain Formation in the northern Ogilvie Mountains.

Spiriferella yukonensis n. sp. is found mainly in siltstone of the unnamed new formation between the Ettrain and Jungle Creek formations, as well as at the base of the Jungle Creek Formation in the northern Ogilvie Mountains, and in the basal siltstone of the Jungle Creek Formation in the Tatonduk River area. The species occurs in a range of lithologies---in sandy siltstone, calcareous siltstone and muddy siltstone---but it is rare in granular carbonate and absent from coarse sandstone and conglomerate in the middle of the formation.

Eridmatus petita n. sp. is found in both siltstone and carbonate of fine sand grains, bearing large scattered brachiopod shells. It occurs in the northern Ogilvie Mountains and in the Peel River area, and appears to have inhabited a range of lithofacies during cool episodes (Eka, Eta) of the Early Permian Period in the Yukon Territory.

A contemporary species, *Alispiriferella ordinaria* (Einor), found in upper Asselian siltstone of the inshore Peel River area, persisted to Sterlitamak time in virtually always the same silty facies, in the Peel River and northern Ogilvie Mountains.

A second species found in beds of the same age as *Alispiriferella ordinaria*, but not with it, is *Spiriferella pseudodraschei* Einor. This is a very abundant species, restricted to beds of Sakmarian age and found in a variety of lithofacies, ranging from mudstone to sandstone, and carbonate over the northern Yukon Territory from Tatonduk River to the Richardson Mountains. *Spiriferella saranae* (de Verneuil) was another Sakmarian species found with *S. pseudodraschei* at only one or two localities, so rarely that the two could have been intermixed after death, or collected from more than one fossil layer. Any complete explanation of why the two species should alternate in dominance must await analysis of the accompanying faunas. The shapes of the two species differ considerably, *S. saranae* being as a rule an elongate shell with massive enrolled ventral umbo, providing an object difficult to topple, whereas *Spiriferella pseudodraschei* had a short, less enrolled ventral umbo and wider, more transverse shape. *Spiriferella saranae* is on the whole more characteristic of silty lithofacies and thus was especially common in the Peel River area, judged to have been an inshore facies. In contrast, *S. salteri* is usually found in more coarse grained rock, especially in the *Yakovlevia* Zone in the northern Ogilvie Mountains, and to some extent in the Tatonduk rather than the Peel River area.

Spiriferella pseudotibetana is found mainly in the Tahkandit Formation, in beds of Baigendzinian age near the Tatonduk River. It occurs in grits, breccias, and limestones of coarse skeletal texture, which probably were deposited in shallow, fairly active waters close inshore. Rare specimens are found also in calcareous grit and granular carbonate in the Belcher Channel Formation of the Sverdrup Basin. Less typical, more elongated specimens are found also at GSC locality 47947 on Bjorne Peninsula in clean, well washed skeletal limestone.

Large ventral valves of approximately the same age, from Mount Burgess, north of Tatonduk River, appear to belong to *Spiriferella vaskovskii* Zavodowsky. Lithology was not described by Nelson and Johnson (1968).

Spiriferella loveni (Diener) = *parryana* (Toula) is known widely from a variety of lithologies in beds of Filippovian to Kazanian age. In the Tatonduk River area, the species occurs in the fine and coarse limestones of the *Pseudosyrinx* Zone in the Tahkandit Formation. It has been found also in a range of sediments: in fine shelly limestone, coarsely skeletal limestone, fine sandstone and coarse green sandstone of the Assistance, van Hauen and Trold Fiord formations of the Arctic Islands. More restricted in distribution, *Spiriferella keilhavii* (von Buch) is found in Nevolin and Kazanian beds of the Sverdrup Basin, ranging from shallow-water green sandstone, to offshore, slowly deposited carbonates. The two species *S. loveni* and *S. keilhavii* were mutually exclusive but no distinction in time or lithofacies is immediately apparent. The elongated shape typical of some *keilhavii* and the more transverse outline of many *loveni* were not constant, and both species were large. The deep median groove of the dorsal fold in *loveni* suggests some difference in feeding.

Timaniella harkeri Waterhouse overlapped both *Spiriferella loveni* and *S. keilhavii* in time range (Filippovian-Irenian) and communal association. It has a long hinge and slight inflation, and is restricted mainly to fine sandstone of the northern Richardson Mountains, and Assistance Formation of the Sverdrup Basin. Rarer species also are known. *Alispiriferella gydanensis* (Zavodowsky) is found in fine sandstone of the Arctic Islands, of Filippovian age. A large species, *Spiriferella leviplica* n. sp., is found only in dense or coarse shelly skeletal carbonates of the van Hauen Formation, of Nevolin-Kazanian age, deposited offshore in the Sverdrup Basin; and *S. vojnowskii* Zavodowsky occurs in granular skeletal carbonate of the Degerböls Formation, of Kazanian age. *Elivina cordiformis* n. sp. was restricted to silty carbonates of Nevolin age in the northern Richardson Mountains. Its hinge is very narrow and its shape is presumably relatively unstable, so that it was substantially buried in sediment.

Table 3. Occurrences of species of Canadian Arctic Spiriferellinae according to lithologies

LITHOLOGY

Carbonate with grain size indicated .... C; Absent from available (contemporaneous) facies .. —; Spiriferellinae according to lithologies X	Breccia	Grit, granular carbonate	Coarse sandstone, or carbonate	Medium sandstone	Fine sandstone	Silty sandstone	Siltstone	Mudstone	Black limestone	White limestone	Silty limestone	Plant mudstone
Timaniella harkeri	—		—		X	X			—	—	—	
Elivina cordiformis	—		—	—			X		—	—	—	
Spiriferella leviplica	—		—	—			X		X	—	—	
Alispiriferella gydanensis					X		X				X	
Spiriferella vojnowskii	—		—	C			—		—	—	—	
S. keilhavii			C X	C			X		X	X	X	
S. loveni	X		X	X C	X C		X			X	X	
S. pseudotibetana	X	X C	C	X								
S. saranae		X		—	X	—	X					—
S. pseudodraschei		—		X C	X	X	X	X				
Alispiriferella ordinaria				—	—	—	X					
Eridmatus petita					X		X		X	X		
Spiriferella yukonensis				C	C		X C	X			X	
Plicatospiriferella canadensis		—	—	—							X	
Spiriferella primaeva		—	—	—							X	

(Lithologies for *S. vaskovskii* and *S. arctica* have not been stated) GSC

World distribution

Middle and Upper Carboniferous (Moscovian to Orenburgian)

As far as can be gathered from the literature, the genus *Spiriferella* first appeared in the Soviet Union (Table 4, Fig. 22). Menner et al. (1970) recorded specimens from northern Haraulakh and Orulgania in the upper Tiksin Suite as *Spiriferella gjeliensis* Stepanov, which supposedly ranges into Lower Permian beds in Petchora (Mergelist Horizon). The Tiksin beds are considered to be basal Middle and upper Lower Carboniferous. They are perhaps as old as, or slightly older than, the Makarov fauna of Taimyr Peninsula, of approximately early Moscovian age (Vereiian to Kashirian), or Bashkirian according to Ustritsky (1971). The Tiksin *Spiriferella* have fewer plicae than does *Plicatospiriferella gjeliensis* (Stepanov), which was described originally from Late Carboniferous faunas of the Bashkirian Urals. *Spiriferella praesaranae* Stepanov 1948, a contemporaneous and possibly conspecific *Plicatospiriferella*, was recorded originally from Gshelian faunas of the Bashkirian Urals, and by Mironova (1967) from the Kasimovian, Gshelian and Asselian faunas of the same region.

The oldest members of the Spiriferellinae found in the Canadian sequences are two species in the *Praehorridonia* Zone of the Peel River area, which are believed to be of Podolian age, or slightly younger than *Spiriferella* of the Tiksin Suite. One species, *Spiriferella primaeva* n. sp., has low plicae, shallow dorsal groove and rounded outline. The second, *Plicatospiriferella canadensis*, is close to *Plicatospiriferella gjeliensis* (Stepanov); it has concave posterior walls, numerous fine plicae and a dorsal umbo in the Russian, though not in the Canadian, shell. These Russian and Canadian species suggest that the Spiriferellinae already had become differentiated by mid-Moscovian time. In the Yukon the apparent absence of species from the underlying and only slightly older ?Kashirian faunas of the *Buxtonia* Zone, and from the early Moscovian (?Vereiian) or Bashkirian faunas of the *Martiniopsis* Zone suggests that the genus had evolved elsewhere, and had migrated into the region.

Spiriferella primaeva persisted into late Moscovian faunas of the *Gibbospirifer* Zone in the Yukon. *Spiriferella yukonensis* n. sp. characterized the Upper Pennsylvanian (Kasimovian to Orenburgian) deposits of the "D" fauna in the Yukon Territory, entering the *Orthotichia-Septospirifer* brachiopod zone, of Kasimovian or Gshelian age approximately, and persisting into deposits of Orenburgian age. The species is likely to have descended from *Spiriferella primaeva* by growing larger and developing stronger plicae. It resembles *primaeva* in shape and narrowly grooved dorsal fold.

Dunbar and Condra (1932) recorded *Neospirifer (Spiriferella) texanus* (Meek), now *Eridmatus*, from the Lenapah Limestone of Oklahoma, of late Desmoinesian age. Some Oklahoma specimens, to judge from figures, are small and gently plicate, bearing many outer fine plicae and a grooved dorsal fold, resembling very closely typical *Spiriferella*. The species *texanus* was described

Table 4. Range of spiriferellinid species in Yukon Territory and Canadian Arctic Archipelago

BRACHIOPOD ZONE

Range in Canada .... —; Range elsewhere X	*Praehorridonia* (Cp)	*Gibbospirifer* (Cgb)	*Kozlowskia* (Dk)	*Septospirifer* (Dos)	*Camerisma* (Dc)	*Schuchertella* (Ds)	*Kochiproductus* (Eka)	*Orthotichia* (Eo)	*Tomiopsis* (Eta)	*Yakovlevia* (Ey)	*Attenuatella* (Ea)	*Tornquistia* (Et)	*Jakutoproductus* (Ej)	*Antiquatonia* (Fa)	*Sowerbina* (Fs)	*Neochonetes* (Fn-Fps)	*Lissochonetes* (Fl-Ft)	*Cancrinelloides* (Gc)
Timaniella harkeri																—	—	
Elivina cordiformis																	—	
Spiriferella leviplica																		—
Spiriferella vojnowskii																	?	
Alispiriferella gydanensis																—		—
Spiriferella keilhavii																?	—	—
S. loveni																—	—	—
S. vaskovskii															?-			
S. pseudotibetana														—	—			
S. saranae									X	—	X	X	—					
S. pseudodraschei										—	?		—					
Alispiriferella ordinaria									—	—	—							
Eridmatus petita						?	—	—	—									
Spiriferella yukonensis			—	—	—	—												
S. primaeva	—	—																
Plicatospiriferella canadensis	—																	

GSC

originally from the lower Cisco Group (probably the lower Graham Formation) of early Virgilian age and has been reported also in the Graford Member (early Missourian) of the Canyon Formation (Dunbar and Condra, 1932, p. 340; Branson, 1966). It has a low ventral umbo that is relatively broad, a wide alate hinge and costate fold with a shallow median groove. Inner plicae are broad and lateral plicae are narrow.

It is somewhat like *Spiriferella asiatica* Volgin 1959 (=*Eridmatus*?) from the Upper Carboniferous of Fergana, which has costate plicae and high ventral umbo.

Asselian

Asselian beds in northern Yukon Territory (Tables 4, 5, Fig. 22) are characterized by *Eridmatus petita* n. sp. *Spiriferella altaica* Besnosova from the Romanov Suite, C3, P1, Kokpecten Group, of Kazakhstan has a massive ventral umbo, a shallow sulcus bearing sturdy costae, and low costate plicae. The incompletely described *Spiriferella mica* Barkhatova (1968) from the Nenetz beds of Timan (Barkhatova, 1962) may be allied closely, or senior synonym. The origins of *S. altaica* are difficult to ascertain, but it probably diverged from *yukonensis* stock by changing its shape. *Spiriferella ploskajae* Zavodowsky from the upper Asselian Paren Horizon is like *S. yukonensis* but has a low ventral umbo; it resembles younger species such as *S. saranae*.

Spiriferella turusica Chernyak (in Ustritsky and Chernyak, 1963, Pl. 37, figs. 1-3), from the Turuzov faunas of Taimyr Peninsula, is poorly known. It has, apparently, alate extremities with an incurved ventral umbo, simple numerous plicae (six pairs), and a narrow anteriorly grooved fold. It possibly arose from or belongs to *Plicatospiriferella* and Chernyak compared it to *praesaranae* of this genus. The age of the Turuzov faunas is not certain; it possibly ranges from Late Carboniferous to Early Permian (see Waterhouse, 1976, p. 55).

Eridmatus marathonensis Cooper and Grant 1976 occurs in the *Uddenites* Zone of Surenan age in the Gaptank Formation.

Specimens of unusual *Spiriferella* from Spitzbergen in the Treskelloden beds of Early Permian age were recorded by Czarniecki (1969, Pl. 15, fig. 5) as *Spiriferella* cf. *polaris* Wiman. Obscure "*keilhavii*" from the Carnian Alps (Tresdorferhöhe) may be allied (Seelmeier, 1937). Czarniecki spiriferacean with smooth fold as *Spiriferella* sp. from the Treskelloden beds. It is transverse and, if it does belong to *Spiriferella*, is a most unusual form, but it is probably not congeneric.

Spiriferella saranae (de Verneuil) has been reported widely from Asselian beds of the Urals (Likharev, 1966), but the identity of the Asselian shells is a matter for doubt, as they do not necessarily possess the fold characteristic of *Spiriferella saranae* sensu stricto. The shells, whatever their name, increased in size over the other species and developed a massive enrolled ventral umbo, high interarea, and narrow fold, and a narrow groove commencing at the dorsal umbo and widening and deepening anteriorly. They are similar to *S. ploskajae* Zavodowsky and resemble *S. altaica* Besnosova less closely.

Spiriferella rajah (not Salter) of Reed (1925, Pl. 6, figs. 3-8) from ?Asselian beds of Chitral may be allied to *S. saranae* (de Verneuil), together with *Spiriferella* sp. of Legrand-Blain (1968, Pl. 4, figs. 10, 11) from Afghanistan. These are the earliest known *Spiriferella* from the Permian Southern Hemisphere.

A completely different strand is represented by the appearance, in upper Asselian beds of the Peel River, Yukon Territory, of *Alispiriferella ordinaria* (Einor) with alate cardinal extremities and a broad dorsal fold bearing a wide sulcus. No immediate forebears are obvious and evolution from either *Eridmatus* or *Plicatospiriferella* stock must have involved considerable morphological change, although both are alate. The species *ordinaria* is found also in Novaya Zemlya, in beds of possible Asselian age, but more likely Sakmarian. It has been listed also from the Telford Formation of the Canadian Rocky Mountains, Alberta, by Logan and McGugan (1968, p. 1131). This formation is at least in part Asselian and bears *Attenuatella* and *Tomiopsis* (Waterhouse, 1971a). *Spiriferella saranae* and so-called *S. rajah* were listed from the same fauna.

Elivina tschernyschewi n. sp. is widespread in the Asselian and Sakmarian Lower Permian of the Urals, as *Spiriferella* (or *Elivina*) *tibetana* Chernyshev (not Diener). Late Asselian shells of somewhat similar shape were described from Kham Keut, Laos, by Mansuy (1913, Pl. 5, fig. 11, Pl. 6, fig. 1a-d), but the Laotian shells have a more extended ventral umbo (see Waterhouse, 1966, p. 55). Shells closely resembling them were recorded as *Spirifer tibetanus occidentalis* Schellwien (1900, Pl. 11, figs. 10-13) from beds at Teufelsschlucht, Neumarkt (Trogkofel beds of Aktastinian age). Possibly they are to be regarded as a species of *Elivina*, although they were compared to *Spirifer lyra* (=*Eliva*) by Seelmeier (1937, p. 104, Pl. 5, figs. 15, 16), because the sulcus in the dorsal fold is narrow; no details on micro-ornament or interior are available.

Sakmarian

Sakmarian faunas in Yukon Territory (Tables 4, 5, Fig. 22) contain three well defined species, *Spiriferella pseudodraschei* Einor, *S. saranae* (de Verneuil) and *Alispiriferella ordinaria* (Einor). *Spiriferella saranae* appears to have radiated from its early ?subtropical habitat in the Urals and ?Afghanistan-Chitral into Arctic Canada and Yukon Territory, Spitzbergen and Alaska. It occurs widely in Siberia, including Novaya Zemlya. In northeastern Siberia, it is present as, or is closely related to, *S. kolymaensis* Zavodowsky in the Yasachnin and Irbichan horizons, and perhaps to the poorly known species *S. bitutchensis* Abramov in the Echi Horizon.

The Canadian species, provisionally identified as *Spiriferella pseudodraschei* Einor, has a very broad but short and slightly incurved ventral umbo, smooth or costate plicae and a long ridge in front of the ventral muscle field. It is very abundant in the Ogilvie Mountains and elsewhere in the Yukon, and is found also in Oregon in poorly dated beds of late Asselian and perhaps Sakmarian age. An obscure shell from the Buttle Lake Formation of Vancouver Island, figured as *Spiriferella* cf. *S. saranae* by Yole (1963, Pl. 1, fig. 6), may be allied. Apparently identical shells occur in Novaya Zemlya, and *S. pseudosaranae* Einor from Novaya Zemlya is similar. Another ally or synonym is *Spiriferella parva* Cooper, erected for a narrow shell with a very high fold in beds of Sakmarian-Asselian age in Oregon. *Spiriferella pseudodraschei* may have originated from *Spiriferella altaica* Besnosova found in the lower Asselian Kokpecten Suite of Kazakhstan.

Alispiriferella ordinaria persisted from upper Asselian beds in the Sakmarian deposits of the Yukon Territory, and is found also in Novaya Zemlya.

Spiriferella salteri Chernyshev from the Sakmarian of the Urals, and perhaps the Ilibei beds of Timan (Barkhatova, 1970), is a distinct species, moderately allied to the predominant *saranae* lineage, but its dorsal valve is poorly known. *Spiriferella digna* Barkhatova (1968, 1970) from the Sakmarian Pel horizon of Timan has high simple plicae, but is indeterminate, with no dorsal valve described. It may have been ancestral to *S. timanica* and *S. vaskovskii*.

Spiriferella interplicatus baschkirica Chernyshev of Tastubian age in the Urals has a transverse subalate appearance. It is not well known to us and could be a transverse development from either the *S. saranae* lineage or from *Eridmatus*. Poorly preserved specimens have been assigned to *baschkirica* from Nassfeld, Grenzland bank, in the Carnian Alps, Austria, by Heritsch (1935, Pl. 1, fig. 5), and from Tresdorferhöhe by Seelmeier (1937, p. 103, Pl. 5, fig. 19). The latter is associated with so-called *keilhavii* not von Buch (Seelmeier, 1937, Pl. 5, fig. 17), but its dorsal valve is poorly known. They are possibly of late Asselian age, but cannot be identified with certainty from the poor figures.

Thomas (1967) listed elongate spiriferellin shells from the Sterlitamakian Callytharra Limestone of Western Australia, which belong to *Elivina*.

Early Permian *Spiriferella* recorded from Kashmir by Bion (1928) are in fact *Tomiopsis* (=*Ambikella*), as shown by Waterhouse (1965). So-called *Spiriferella personata* Reed (1932) and *S. kimsari* Reed (1932) from Kashmir are not congeneric with *Spiriferella* either.

Baigendzinian

Baigendzinian faunas of the Yukon Territory (Tables 4, 5, Fig. 22) contain a widespread species of *Spiriferella*, possessing simple strong plicae and a rounded fold with a very shallow groove anteriorly. They may belong to *Spiriferella pseudotibetana* Stepanov, a species which is very close apparently to *S. saranae* (de Verneuil) and *S. kolymaensis* Zavodowsky from slightly older faunas, and distinguished by the fold, which is rounded posteriorly. The species is found also in Krasnoufimian beds of Kolwa region, northern Urals. It is related closely to and possibly senior synonym of *Spiriferella nalivkini* Kulikov, which is based on a very narrow elongated shell from the *Parafusulina lutugini* beds of the Urals.

Spiriferella vaskovskii Zavodowsky is represented in the Yukon Territory as large, simply ribbed shells in beds of possible Baigendzinian age, described by Nelson and Johnson (1968). The species, probably a close ally of *saranae*, was described originally from the Djeltin horizon (Baigendzinian) of the Kolyma River region, northeastern Siberia. It has a costate broad fold, with no costae or groove posteriorly, and so is close to other species of this age.

Before Baigendzinian time, shells with a round-crested dorsal fold were rare, but they included Sakmarian (sensu lato) shells here named *S. barkhatovae* n.sp. and figured incorrectly as *Spiriferella saranae* (not de Verneuil) by Chernyshev (1902) (cf. also von Keyserling, 1846, Pl. 8, fig. 5; and perhaps Ifanova, in Ifanova and Semenova, 1972).

Barkhatova (1970) reported *S. polaris* with a similar fold, from the Komichan Horizon of Baigendzinian age in Timan, together with the distinctive *S. timanica* Barkhatova 1962, which has smooth fold and plicae.

Spiriferella waageni (Chernyshev) from Artinskian (probably Baigendzinian) beds of the Urals is very close to and presumably descended from *Spiriferella pseudodraschei* Einor. It has a low ventral umbo and a very faint groove on the dorsal fold.

According to Ifanova (in Ifanova and Semenova, 1972), *Spiriferella draschei* (Toula), here synonymized with *S. keilhavii* (von Buch), entered the northwestern Russian sequences of Pai Hoi in the Talatin horizon of late Artinskian age. This species became widespread over Arctic seas during the Kungurian. The Talatin specimen has a groove anteriorly on the fold, but is a narrower shell than usual for *keilhavii*. It probably descended from *saranae* stock, perhaps *S. kolymaensis* Zavodowsky.

Spiriferella pajchoica Ifanova from the Talatin horizon of Pai Hoi is a transverse alate species with a well rounded costate dorsal fold, possibly from *S. pseudotibetana* or *S. timanica*, having developed an alate outline and broad umbo. More remotely, it may have lost the dorsal groove in developing from *S. baschkirica* of the Sakmarian Stage.

Transverse simply plicate ventral valves bearing broad umbones, from the Amb Formation, Salt Range, Pakistan, in the Southern Hemisphere during the Permian Period, were compared by Reed (1944, Pl. 27, figs. 10, 11) with *Spiriferella saranae* (de Verneuil), but the shells obviously are not conspecific with de Verneuil's species. They appear to be allied to *S. pajchoica*, though lacking such alate extremities.

The elongate *Spiriferella australasica* Etheridge (1889, 1914) has a flat-crested, dorsal fold with short groove, and comes from Western Australia from the Byro Group, which is chiefly of Baigendzinian age. The species closely resembles *S. pseudotibetana* Stepanov of Russia and Canada.

Thus, during the Baigendzinian Stage, *Alispiriferella* or *Spiriferella* with a broadly sulcate dorsal fold are not known and, instead, several species developed or flourished which had a very shallow anterior groove (*pseudotibetana, nalivkini, vaskovskii, australasica*), or no sulcus at all (*timanica*) on the fold. The significance of this is far from clear, but it is known that the Baigendzinian was a warm episode in the earth's history, without the widespread evidence for glaciations of the preceding Sakmarian and Asselian stages, when folds were sulcate. The *pseudodraschei* lineage or superspecies with grooved and costate fold and transverse lineage also persisted. *Elivina* is not known for certain.

Kungurian

The Kungurian Stage saw great proliferation of various *Spiriferella* stock (Tables 4, 5, Fig. 22), including development of a new genus, *Timaniella*, conceivably from *Alispiriferella* stock, and the renewal of various other strands, including diversification of forms with rounded dorsal fold.

Two major species are found in the Kungurian faunas of northern Canada. *Spiriferella loveni* (Diener) entered the Filippovian Assistance Formation of the Arctic Islands and *Pseudosyrinx* Zone of the Tahkandit Formation in the Tatonduk River area. It is a species of large shells, with variable outline and deep groove in the fold. It seems unlikely that it descended from *Alispiriferella ordinaria*, which also has a sulcate dorsal valve, because the general shape differs so much. Instead, an origin from *S. saranae* or allies is proposed. The species is found widely in the Arctic, in Spitzbergen, Greenland and Novaya Zemlya. A somewhat allied species, *Spiriferella keilhavii* (von Buch), entered the Canadian sequences in the Nevolin equivalents, and varied in outline from transverse to elongate. The species is found widely in the Arctic, including Spitzbergen, Greenland and Alaska, and perhaps from the Kolyma massif (as *S. "rajah"*) and in northeastern Siberia (or as the allied *S. burgaliensis* Zavodowsky in the Djigdalin beds of Filippovian age). *Spiriferella keilhavii* probably originated from *S. saranae*. *Alispiriferella gydanensis* (Zavodowsky), found in fine sandstone of the Assistance Formation, is a descendant from *A. ordinaria* (Einor), and it persisted into the Kazanian Omolon horizon of Kolyma River, Siberia.

A new genus, characterized by transverse shape and sulcate fold, developed as *Timaniella* during Kungurian times. *Timaniella harkeri* characterized Filippovian and Nevolin faunas of the Yukon Territory and Arctic Archipelago. A somewhat similar form was described by Frederiks (1925) as *S.* cf. *vercherei* not Waagen from beds of probable Nevolin age at Cape Kalouzin, Ussuriland, and another ally occurs in the Cache Creek brachiopod faunule at Kamloops, British Columbia. *Timaniella festa* Barkhatova, which has a wide, deep groove in the dorsal fold, comes from Kungurian beds of the Vil horizon in Timan and may be present in Spitzbergen. *Elivina*, scarce in Baigendzinian faunas, reappeared as a new species, *E. cordiformis* n. sp., in the Nevolin beds of the northern Richardson Mountains, Yukon Territory.

Table 5. Occurrence and age of species of Spiriferella, Alispiriferella, Timaniella, Eridmatus *and* Elivina *in Permian Period*

Substage	Northern Hemisphere	Tropical realm	Southern Hemisphere
Dienerian			
Griesbachian			*S. rajah* (derived?)
Ogbinan Vedian			*Spiriferella* spp., *S. rajah*
Baisalian Urushtenian		*S. sulcifer*, *E. annectens*, *E. detecta*	
Chhidruan	*S. rajah*		*S. rajah*, *S. vihiana*, *E. tibetana*? *E. semiovalis*
Kalabaghian		*S. cambodgiensis*, *S. sulcifer*, *E. compacta*, *E. annectens*	*S. rajah*, *S. ?kupangensis*, *E. tibetana*, *E. tenuisulcata*, *E. semiovalis*
Sosnovian		*S. clypeata*, *S. propria*, *S. calcarata*	
Kalinovian	*A. gydanensis*, *S. keilhavii*, *S. loveni*, *S. leviplica*, *T. irbuchanensis*, *E. mongugayensis*	*S. gloverae*, *S. gravis*, *S. calcarata*	
Irenian (=Ufimian - Nevolin)	*S. scobina*, *S. vojnowskii*, *S. talbeica*, *S. lita*, *S. keilhavii*, *S. loveni*, *T. harkeri*, *E. cordiformis*, *S. mongolica*, *S. persaranae*	*S. levis*, *T.* aff. *T. harkeri*, *S.* ?aff. *supplanta*, *S. calcarata*, *S. embrithes*	*Spiriferella* (Afghanistan, W. Australia, Thailand), *S. supplanta*
Filippovian	*S. keilhavii*, *A. gydanensis*, *S. scobinoidea*, *S. lita*, *S. polaris*, *S. loveni*, *T. festa*, *T. harkeri*	*S. scobinoidea*	*Spiriferella* (Timor)
Krasnoufimian - Sarginian	*S. waageni*, *S. keilhavii* *S. pseudotibetana*, *S. pajchoica*, *S. ?nalivkini*, *S. vaskovskii*		*S.* aff. *pajchoica*, *S. australasica*
Aktastinian	*S. saranae*, *S. salteri*, *E. occidentalis*, *S. pseudodraschei*		
Sterlitamakian	*A. ordinaria*, *S. digna*, *S. saranae*, *S. salteri*, *S. barkhatovae*, *S. pseudodraschei*		*Elivina*
Tastubian	*S. baschkirica*, *S. pseudodraschei*, *S. salteri*, *S. saranae*, *A. ordinaria*, *E. tschernyschewi*		
Kurmaian	*S. ploskajae*, *S. ?baschkirica*, *E. tschernyschewi*, *Er. turusica*, *Er. petita*, *A. ordinaria*	aff. *E. tschernyschewi*	*S. ?saranae*
Uskalikian	*S. mica*, *Er. petita*		*S. ?saranae*
Surenan	*S. ?saranae*, *Er. petita*, *?E. occidentalis* (or Kasimovian)	*S. altaica*, *Er. marathonensis*, *Er. texanus*?	

Paleogeographic subdivisions after Waterhouse and Bonham-Carter (1975).

Another species, restricted in Canada to beds of uncertain age in the Yukon Territory, is *Spiriferella vojnowskii* Ifanova, originally described from Kungurian faunas of the Aryarchyargin beds and Adzvin Suite in northeastern Russia (Timan-Petchora). The species has a low umbo, and may have been derived from *S. waageni* and *S. pseudodraschei*, but this is not entirely certain; alternatively, it is of the *keilhavii* group. Of interest also is *S. talbeica* Ifanova (in Ifanova and Semenova, 1972) from the Kungurian Upper Aryarchyargin beds. This small species, which has massive ventral shoulders, a small, little-incurved ventral umbo and costate plicae, and a peculiar ventral muscle platform, may be descended from the Sakmarian species *S. pseudodraschei* Einor, through *S. waageni* (Chernyshev), of Baigendzinian age in the Urals. However, it has a high, nongrooved fold, and could be descended from *S. timanica*, as its umbo is only slightly lower than *timanica*'s. It recalls *S. salteri* (Chernyshev) but has no ears.

Another Kungurian species is *Spiriferella polaris* (Wiman) (1914), from Spitzbergen. It has a round-crested dorsal fold and high simple plicae, and probably is descended from *S. timanica* Barkhatova of Baigendzinian age in Timan. What appear to be somewhat similar specimens were figured from Kungurian beds of the Urals by Kulikov (1974, Pl. 6, figs. 7 - 9).

Spiriferella saranae lita Frederiks (1925, Pl. 1, figs. 16 - 27) comes from a Kungurian fauna in Ussuriland. The type specimens are small, bearing simple plicae and moderately prominent ventral umbo, with concave posterior walls. The dorsal fold is rounded with a median groove that is variably formed, often faint, and narrower than that of *S. loveni*. Material from Ussuriland in collections held by Dr. G.V. Kotlyar, VSEGEI, Leningrad, somewhat resemble *S. loveni* in the simple plicae and grooved dorsal fold. Sketches by Frederiks (1934, Pl. 3, fig. 25a, b) of specimens purporting to be *S. saranae lita*, from a fauna of probable Kungurian age at Ashi-Ho, Manchuria, cannot be interpreted with confidence, but also suggest somewhat similar specimens. Nonaka (1944, Pl. 7, figs. 12 - 14) recorded *S. saranae lita* Frederiks from poorly dated Permian beds of Mongolia at West Ujimuchin. His specimens are moderately close but, since only ventral valves are figured, it is difficult to be sure.

Numerous so-called species were identified by Grabau (1931) from the *Spiriferella* and *Marginifera* beds of Mongolia in beds of probable Kungurian age (Waterhouse, 1976), though the faunas have not been precisely dated (Table 6). From the basal faunas, *Spiriferella persaranae* Grabau apparently is allied to the transverse species *baschkirica*. It is not possible to identify because the dorsal valve is not known, and the ventral valve poorly preserved. Some specimens from the middle Jisu Honguer faunas look like *Spiriferella rajah* (e.g., Grabau, 1931, Pl. 22, figs. 1a, 2a). Another form, miscalled *Spiriferella keilhavii*, has a grooved fold like that of *S. loveni* (Diener) (Grabau, 1931, Pl. 20, fig. 9a), and also may prove to be related to *S. vihiana* (Davidson) from the Punjabian of the Himalayas. Many other variously named shells belong to one species, all referable to *Spiriferella mongolica* Grabau, originally named as a variety of *S. salteri* Chernyshev. The species is characterized by an extended ventral umbo, long concave posterior walls, and a well formed costate fold. It possibly is descended from *salteri*.

From the Monos Formation of El Antimonio, western Sonora, northern Mexico, *Spiriferella scobinoidea* Cooper (1953) has a prominent incurved, ventral umbo, sturdy plicae and a costate dorsal fold, and approaches *S. keilhavii* (von Buch). The species comes from the *Anidanthus* Zone. Only a general mid-Permian age was assigned, but the species is here considered to be of Kungurian and perhaps Filippovian age.

According to Cooper (1953), *Spirifer scobina* Meek from Utah is a typical *Spiriferella*. As figured by Meek (1876, Pl. 2, fig. 5a - c), since it has obtuse extremities and costate fold and sulcus, it could prove to be allied closely to *S. keilhavii*, and so be of approximately Kungurian or perhaps Kazanian age. *Spiriferella embrithes* Cooper and Grant (1976) from the China Tank Member of Texas looks similar to *S. supplanta* Waterhouse from New Zealand beds of similar age. *Spiriferella calcarata* from the same beds is similar to *S. keilhavii* (von Buch). Regrettably, Cooper and Grant (1976) made no comparisons with species beyond the immediate area of western Texas - New Mexico, so that their species stand under threat of synonymy until their proposed names are validated by comparative studies.

Bitauni faunas of early Kungurian age in Portuguese Timor have yielded *Spiriferella* or *Elivina*? with a rounded dorsal fold, which Shimizu (1966, Pl. 17, figs. 1 - 4) incorrectly assigned to *S. rajah* Salter. Hamlet (1928) recorded the same species from Bitauni of western Timor, and Grant (1976) recorded fragments from Thailand.

Termier et al. (1974) recorded two species of *Spiriferella*, *S. mexicana* (Shumard) and *S. tibetana* (Diener), from the Kubergandin horizon (i.e., early Murgab or Kungurian) from Wardak, Afghanistan. Both are somewhat like *Elivina* in shape, but specific identities are not exactly the same as the species named. Pustules were reported on both.

Undescribed *Spiriferella* with a rounded or flat-crested dorsal fold comes from the upper Noonkanbah (?Nevolin) and Coolkilya (Nevolin) beds of Western Australia (Thomas, 1967; Archbold, 1976). It is clearly allied to *S. polaris* (Wiman) of similar age in the Arctic.

In the Letham Formation of Nevolin age in New Zealand, *Spiriferella supplanta* Waterhouse (1964) resembles closely *S. keilhavii*, from which it is distinguished mainly by its alate hinge and narrow but deep groove along the dorsal fold. Somewhat similar specimens are found in the Cache Creek Group of British Columbia, in the Kungurian, perhaps ?Nevolin fauna from near Kamloops. They were identified incorrectly by Crockford and Warren (1935) as *Spiriferella interplicatus baschkirica* Chernyshev. These Canadian specimens are close also to *S. embrithes* Cooper and Grant from Texas, a form very similar indeed to *S. supplanta*.

Table 6. Summary of species of Spiriferella *described by Grabau (1931), in the Jisu Honguer beds of Mongolia*

Locality	Species of *Spiriferella*	Age
1193, 1194, 1211?	None	
1205, 1207, 1208	*S. "rajah"* *S. mongolica*	Irenian
1209, 1210	*S. rajah* not Salter *S. mongolica* *S.* cf. *vihiana-loveni*	Irenian
1190, 1192	*S. persaranae* Grabau	?Filippovian

Kazanian

In the Kazanian Trold Fiord and Degerböls formations of the Canadian Arctic Archipelago (Tables 4, 5, Fig. 22), *Spiriferella loveni* (Diener) and *S. keilhavii* (von Buch) were joined by *S. leviplica*, an unusual *Spiriferella* with smooth plicae and wide groove in the dorsal fold, possibly descended from *S. loveni*.

The Mount Greene beds in the Rocky Mountains in northeastern British Columbia, of approximately Kazanian age, contain *Spiriferella* identified as *S. rajah* (Salter) by Logan and McGugan (1968, p. 1130); the species is perhaps *keilhavii* (von Buch).

Spiriferella sp., figured by Cooper (1953), from the upper Monos Formation of northern Mexico, looks fairly similar to *S. loveni* (Diener) and is of approximately Kazanian age, judged from our analysis, although Cooper (1953) provided no firm correlations.

A number of forms from the Appel Ranch and Willis Ranch members of Kazanian age in west Texas have been named by Cooper and Grant (1976), including *S. calcarata* (also found in the Irenian Cherry Canyon and Getaway faunas in this region), *clypeata*, *gravis*, *propria* and *levis*, and also *gloverae* (found in the Cherry Canyon and Getaway beds). Each 'species' differs within extremely narrow limits, recalling the various individuals assigned to *keilhavii* by Dunbar (1955).

Timaniella apparently persisted as *Spiriferella irbuchanensis* Zavodowsky (1970) in the Omolon horizon, of Kazanian age in eastern Siberia.

An obscure dorsal valve of *Spiriferella* with many costae was figured from mid-Permian beds of Yunnan by Reed (1927, Pl. 14, fig. 8).

Punjabian

Faunas of Punjabian age are very widespread (Tables 4, 5, Fig. 22). Individuals of the Spiriferellinae are abundant, especially in the Tethyan fringes of Gondwana, now exposed through the Himalayas, southeastern Asia and Timor, and extending into western United States. *Elivina*, or at least shells shaped like that genus, with short hinge, became especially prominent. Capitanian shells from New Mexico, United States, include three species: *compacta* Girty, *annectens* Cooper and Grant and *detecta* Cooper and Grant. The third species is unusual in having fine costae and inconspicuous plicae. The description makes no mention of plicae. Girty (1909, Pl. 13, fig. 10) also refigured Shumard's original of *Spirifer sulcifer* from the same beds, showing a smoothly plicate form with anterior median groove in the fold and anteriorly costate sulcus. The species, as interpreted by Cooper and Grant (1976, p. 2235), probably is allied to *loveni* rather than *keilhavii*.

Elivina tibetana (Diener, 1897) is widespread through the Himalayas, Karakorum and Timor. It has a short hinge, triangular outline and a shallow groove for the length of the dorsal fold. It was described originally from the exotic limestone block of Chitichun no. 1, south Tibet, and evidently characterized southern subtropical faunas of approximately Punjabian (especially Kalabaghian) age. Karakorum material recorded by Merla (1934, Pl. 26, figs. 14 - 21) and Sestini (1965b) as *Spirifer tibetanus tenuisulcatus* Merla is possibly *Elivina*, but it may prove to be a descendant from *Spiriferella pseudosaranae*, to judge from figures. The specimens come from beds tentatively regarded as Kalabaghian in age, but possibly a little older, and indeed were assigned to the upper Artinskian by Renz (1940) and others. Tiny Shaksgam specimens, figured as *Spirifer tibetanus occidentalis* not Schellwien, by Renz (1940, Pl. 6, fig. 8a - d), may be related. Sestini (1965b) included Renz's specimens with others described by Merla (1934, Pl. 21, figs. 20 - 22, 25) in *Elivina tibetana*. All are moderately similar, but are difficult to interpret from figures alone because they are small or distorted. The specimens from the upper Hunza Valley were regarded as Lower Permian by Sestini (1965a) but they could prove to be Kalabaghian.

Elivina tibetana has been recognized also in Timor in Basleo beds correlated with the Kalabaghian substage and from the Amarassi beds, regarded herein as early Chhidruan (see Waterhouse, 1972a, 1976). Ishii et al. (1969) recorded comparable specimens from the Kalabaghian fauna of Sisophon, Cambodia, in Member C.

A shell from the Chhidru Formation, Salt Range, was referred incorrectly to *Elivina interplicatus baschkirica* (Chernyshev) by Reed (1944, Pl. 26, fig. 6). It is a small ventral valve with few costae. *Elivina blasii semiovalis* Reed (1944, Pl. 28, figs. 3, 3a, Pl. 29, figs. 5, 5a) from the upper Wargal and Chhidru beds of the Salt Range, Pakistan, is a small costate transverse shell with protruding ventral umbo and fold split anteriorly by a groove. *Spiriferella scopulosus* Reed from the same horizons appears to be choristitinid rather than spiriferellinid.

Spiriferella rajah (Salter) (in Salter and Blanford, 1865) is a very extensive late Middle Permian species of southern Asia. It was described originally from beds of uncertain age in the Himalayas, and has been recorded from the Himalayas by Davidson (1866), Diener (1899), Muir-Wood and Oakley (1941) and Waterhouse (1966). It looks like *Spiriferella keilhavii* in general shape, and has an alate hinge and slightly longer grooved fold as a rule. Judging from field work by Waterhouse during 1973 in northwestern Nepal, *Spiriferella rajah* is found widely with *Cyclolobus* within the *Lamnimargus himalayensis* brachiopod zone and probably is of Punjabian age. *Spiriferella rajah* and *S. tibetana* occur together in Basleo, Timor, according to Hamlet (1928), where, however, Furnish (1973) reported some admixture of Kazanian (late Wordian) and Kalabaghian (Capitanian) ammonoids. A species of indeterminate affinities also occurs in high Chhidruan beds of New Zealand, in the upper Glendale Limestone (Waterhouse, 1968, in press). Chi-Thuan (1961, Pl. 3, figs. 2, 3) has recorded *S. rajah* from Phnom-Tup near Sisophon, in faunas of late Kazanian or Kalabaghian age, as discussed by Waterhouse (1973a). Laotian specimens recorded by Mansuy (1912) have many plicae and a smooth fold and probably are not congeneric.

A suite of specimens from Vladivostok, eastern Siberia, was figured by Frederiks (1916, Pl. 5) as various subspecies or varieties of *Spiriferella rajah*. Only the ventral aspects were well figured, so that it is difficult to decide whether the specimens are *S. rajah* or *S. keilhavii*, but a Kalabaghian age seems likely. The specimens possibly belong to *S. rajah*, though they are shaped rather like *keilhavii*. *Spiriferella rajah saranaeformis* (Frederiks, 1916, Pl. 5, fig. 3) has a narrow dorsal groove. They also have a high interarea and may not be close to *S. rajah*. Ussuriland collections shown to me by Dr. Kotlyar include forms with deep dorsal grooves and high ventral interareas, somewhat reminiscent of Mongolian shells described by Grabau (1931) as *mongolica*.

Chi-Thuan (1961, Pl. 8, figs. 7, 8) recorded *Spiriferella "salteri"* (not Chernyshev) and *S. salteri cambodgiensis* Chi-Thuan from the upper Kazanian or lower Kalabaghian beds of Phnom-Tup, Cambodia. The figures are obscure, and even the generic identification is not clear. The dorsal fold lacks a groove, and so suggests an alliance with *Spiriferella wimani* or *Spiriferella vojnowskii*. The obscure *Spirifer tupensis* Chi-Thuan (1961, Pl. 6, fig. 6) might even be related to *Spiriferella*.

So-called *Spiriferella* cf. *saranae* mut. *lita* Frederiks from the Kalabaghian *Leptodus richthofenia* beds of the Kitakami Mountains, Japan (Hayasaka, 1926, Pl. 6, fig. 14) is very obscure, but has a wide ventral sulcus and simple plicae.

Several other species are known from southern Asia. *Spirifera vihiana* Davidson (1866) from beds of uncertain age in Kashmir, probably early Punjabian, might prove to be a *Spiriferella*, perhaps related to *S. loveni* because of its deeply grooved dorsal fold. From a Middle Permian fauna in Tibet, Ting (1963) described as *Spiriferella salteri* not

Chernyshev an elongate incurved shell with entire dorsal fold, possibly descended from the *pseudotibetana* and *polaris* superspecies, and related to *kupangensis-cambodgiensis*. The specimen came from north of Mount Everest, presumably in the 'Tibetan Zone'. A somewhat similar shell, described from ?Basleo beds of Timor as *Spirifer kupangensis* Beyrich (1865, Pl. 1, fig. 6a-c), has not been rediscovered during the investigations of Broili (1916) and Hamlet (1928). It is narrow and inflated, with no costae and no groove in the fold, but could be related to *Elivina*. Some 300 m above lower Kuman Fusulinacea *Lepidolina* cf. *toriyamai* Kanmera, *Yabeina* cf. *gubleri* Kanmera and *Y.* cf. *shiraiwensis* Ozawa, from the Mizukoshi Formation of Kyushu, *Spiriferella keilhavii* (not von Buch) of Yanagida (1963) is transverse and in some specimens highly alate, and has simple or costate plicae and fold traversed by a well defined median groove. Specimens have been distorted, so that some are elongate, others transverse. Some look rather like *Spiriferella vihiana* (Davidson) and similar shells from Mongolia (Grabau, 1931). The Japanese shells are likely to be of Chhidruan age. In their transverse outline they resemble *Timaniella* but the sulcus of the dorsal fold is much narrower, though the effect of distortion is unclear.

Dorashamian

Virtually no *Spiriferella* are known from younger deposits (Tables 4, 5, Fig. 22), probably because the sediments with preferred *Spiriferella* habitats are scarce, most Upper Permian deposits being restricted to the paleotropical realm in Armenia, Iran and China. The youngest known occurrences are in New Zealand and Nepal. From New Zealand, Waterhouse (1967) recorded an almost smooth species as *Spiriferella* sp. from the Stephens limestone, of late Vedian age. The dorsal valve is not known. From Nepal in faunas judged to be Vedian in age, *Spiriferella rajah* is found widely and abundantly with *Cyclolobus* in beds well above the *Lamnimargus himalayensis* Zone. An associated species *S. oblata* Waterhouse is also present.

Waterhouse has collected *Spiriferella* from the Griesbachian beds of Nepal, with *Otoceras woodwardi*, but the *Spiriferella* could have been reworked from the underlying beds with *S. rajah*.

Summary

Evolution. From the foregoing review, it appears that several lineages may be discerned among the 50 species recognized in the Spiriferellinae. Even as early as Moscovian time, the Spiriferellinae was polyphyletic, with the multiplicate *Plicatospiriferella gjeliensis* and *P. canadensis* and pauciplicate *Spiriferella primaeva*. *Eridmatus* also arose early, and is rather like the predominant lineage in *Spiriferella*, with a few Middle and Late Carboniferous species found mainly in North America but also known in Asia. Several Permian lineages may be discerned, although their origins are not completely clear. *Alispiriferella*, with deep median cleft in the dorsal fold, was represented in Asselian time by *A. ordinaria* (Einor), followed, after an interval, in the early Middle Permian by *A. gydanensis* (Zavodowsky) and perhaps *S. leviplica* n. sp. *Eridmatus* is perhaps a possible ancestor from Carboniferous time, through very considerable change. The genus was of minor significance, restricted to northern temperate latitudes of the Permian Period.

The tendancy toward alation and the widely grooved dorsal fold of *Alispiriferella* strongly suggest that it gave rise in the early Middle Permian to *Timaniella* Barkhatova, which is represented by two Kungurian species *T. festa* and *T. harkeri*, and a Kazanian species *T. irbuchanensis* (Zavodowsky). The genus was restricted to temperate and low latitudes of the Northern Hemisphere.

Another distinctive lineage probably arose from *Spiriferella primaeva* n. sp. of the Middle Carboniferous, perhaps through the poorly known Asselian forms *S. altaica* Besnosova and *S. mica* Barkhatova, *S. pseudodraschei* Einor = *S. parva* Cooper in the Sakmarian, *S. waageni* Chernyshev in the Artinskian and finally, perhaps, *Spiriferella talbeica* Ifanova (Kungurian). The lineage appears to have originated at relatively low latitudes, and later became restricted to temperate latitudes of the Northern Hemisphere.

The largest, most widespread, and complex lineage is best typified by *Spiriferella saranae* (de Verneuil), a species which was widespread in the Northern Hemisphere and apparently penetrated the Southern Hemisphere also. Its origins are not clear. Specimens are rather like *Spiriferella yukonensis* and *S. primaeva* in shape and ventral umbo and, to some extent, the dorsal fold. *Spiriferella saranae* was related closely to the contemporary species or subspecies *S. ploskajae* Zavodowsky and *S. kolymaensis* Zavodowsky of northeastern Siberia (from *S. yukonensis*?) and perhaps poorly known *S. digna* Barkhatova from Timan. Presumably, *S. saranae* gave rise to *S. pseudotibetana* Stepanov and allied *S. vaskovskii* Zavodowsky, followed by one of the dominant early Middle Permian species, *Spiriferella keilhavii* (von Buch), a large shell rather like *S. saranae*, largely restricted to the Northern Hemisphere. *Spiriferella keilhavii* may have given rise to associated species, such as *S. scobinoidea* Cooper from Mexico.

An ally of *S. keilhavii* was *S. loveni*, which conceivably gave rise to *S. leviplica*, in the Kazanian Stage of the Canadian Arctic, and *S. vihiana* (Davidson) in the Punjabian Stage of the Himalayas.

Spiriferella keilhavii was similar also to a contemporaneous New Zealand species or subspecies *S. supplanta* Waterhouse, and various 'species' named from western Texas by Cooper and Grant (1976). *Spiriferella supplanta* possibly gave rise to the predominant late Middle Permian *Spiriferella*, *S. rajah* (Salter), a species widespread in southern temperate latitudes of the Himalayas to Timor, and possibly represented in Kamchatka, judged from material described by Frederiks (1925).

A further lineage apparently arose from shells allied to forebears of *Spiriferella saranae*. During the Permian, the dorsal fold in some *Spiriferella* tended to develop a well rounded crest. *Spiriferella barkhatovae* of Early Permian age (=*Spiriferella saranae* of Chernyshev, not de Verneuil) gave rise to *Spiriferella timanica* Barkhatova, followed in turn by the Kungurian species *Spiriferella polaris* Wiman. The Cambodian *S. cambodgiensis* Chi-Thuan conceivably arose from this stock.

The *Spiriferella saranae* superspecies apparently was more closely allied to *Elivina* than were the other lineages, and this genus appears to have arisen in Early Permian time nearly concurrently with *S. saranae*. It evolved through a rather limited succession of species found in both hemispheres, with *E. occidentalis* and *E. tschernyschewi* in the northern hemisphere of the Early Permian, followed by *E. cordiformis* in the early Middle Permian. In late Middle Permian time, the genus penetrated the southern hemisphere as *E. tibetana* (Diener) and *E. semiovalis* Reed, whereas *E. mexicanus*, *E. compacta* and *E. sulcifer* are found in Texas - New Mexico.

Distribution. *Spiriferella* was, on the whole, a moderately tolerant genus, and its species lived in from one up to five zones, which is probably close to average for brachiopod species. A few species were widespread geographically and tolerant of a range of lithofacies, whereas other species were more restricted in geographic range and restricted to a few biotopes---especially those found in silty carbonates and siltstones. The temperature tolerance of *Spiriferella* was fairly broad but not great. It is completely absent from very

Table 7. Summary of geographic distribution of spiriferellin species in the Permian Period

Station and temperature belt (biome) for Permian Period	Approx. no. of substages (marine)	No. of species	Approx. ratio	No. of substages with species	Approx. ratio	Total group average
North Temperate	(t)	(s)	(s/t)	(su)	(su/t)	
Kolyma River	?8	9 - 10	1.25	5	0.6	
Taimyr Peninsula	6-7	3	0.5	4	0.57	
Timan, Petchora, Kolwa	?10 - 13	11	1.0	10	1.0	
Urals, Russian Platform	13	7	0.5	9	0.75	
Arctic Archipelago	4 - 5	5	1.0	4	0.8	
Yukon	11	10	0.9	11	1.0	
Group average			0.71			0.82
Tropical						
Armenia	8	0	0.0	0	0.0	
Carnian Alps	6	2	0.33	3	0.5	
Texas, Mexico	11 - 12	15	1.25	6	0.5	
China	8 - 10	0	0.0	0	0.0	
Laos, Cambodia	?8	3	0.33	3	0.37	
Pamirs, Fergana, Kazhakstan	?9	3	0.33	2	0.25	
Group average			0.21			0.32
South Temperate						
Salt Range	9	?3	0.33	?3	0.33	
Timor	4	4	1.00	?3	0.75?	
Western Australia	10	3	0.33	3	0.33	
New Zealand	11	3	0.27	3	0.27	
Group average			0.38			0.48
South Polar						
Queensland	9	0	0	0	0	
New South Wales	9	0	0	0	0	
Tasmania	8	0	0	0	0	
Group average			0			0

Possibly the Pamirs, like Afghanistan, suffered severe cooling in the Early Permian.

cold waters, where tillites and varves were formed close to the late Paleozoic south pole, as in eastern Australia, and it is absent from some very highly diverse faunas associated with reef-building rugose corals and other indices of the late Paleozoic tropical waters (Waterhouse and Bonham-Carter, 1975), as in deposits of southern China and Armenia. It is absent from the Zechstein Sea, perhaps because of high salinity, and rare or absent in the Phosphoria Sea, perhaps because of unusual geochemistry. The genus is rare, together with its associated genus *Elivina* in other purported paleotropical deposits, as in Fergana, Kazakhstan, Laos-Cambodia and Texas - northern Mexico. Species are most common in deposits of a temperate northern paleolatitude in northern Russia, Siberia, Yukon Territory and Canadian Arctic Archipelago. These differences are expressed in Table 7, which by recording the number of brachiopod-bearing stages and number of spiriferellinid species, provides a ratio of the number of *Spiriferella* and allied genera per stage for the Permian Period. The highest values are found in Kolyma River, Canadian Arctic Archipelago, Yukon Territory, northern Russia, Timan, Kolwa Peninsula and Petchora Land. No doubt Novaya Zemlya would be placed here; it is omitted because of uncertainty over the stratigraphic succession.

The Urals and the Russian Platform have a fairly high score at 0.5, and long-awaited revision of the faunas may increase the ratio. In the Southern Hemisphere, Timor shows a high ratio of 1, and Western Australia shows a ratio of 0.5. The genera *Spiriferella* and *Elivina* were widespread in the short-lived mid-Permian succession of the Himalayas, so these regions were likely to have occupied a southern paleolatitude comparable to that of the Arctic Islands and northern Russia - Siberia.

Lower scores are registered for paleotropical areas such as Pamirs-Fergana, Laos-Cambodia and the Carnian Alps of Austria. Moreover, Spiriferellinae would occupy an even more insignificant part of the faunas if ratios were based either on the number of individuals, or on the proportion of spiriferellin species to remaining species in the fauna. It seems surprising that China and Armenia have no species: China is clearly undersampled, and Armenia lacks extensive faunas from the Early and early Middle Permian, when *Spiriferella* was abundant. We are not aware of any occurrences in South America, where outcrops are limited in age. There are warm-water deposits in Peru and Bolivia, and cold-water deposits in Brazil and much of Argentina. For west Texas - New Mexico, the ratio is inflated possibly by excessive nomenclatural splitting. Spiriferellin species are restricted in these sequences to the base of the Lower Permian, and to the Middle Permian above the Road Canyon Member. It appears that *Spiriferella* and later *Elivina* did expand into this region in the mid-Permian.

The well sampled and extensive Permian outcrops of eastern Australia have no *Spiriferella* and New Zealand has comparatively few. Waterhouse (1964) suggested that *Tomiopsis*, which is abundant in eastern Australia and New Zealand, may have competed with *Spiriferella*, since it is of somewhat similar shape.

Significance for Paleoclimatology

The distribution of Permian brachiopods with a predominantly temperate climatic preference has been discussed by Waterhouse (1969, 1971b). The northern and southern faunas did not differ markedly from each other, except in number of species. It appears that *Spiriferella saranae* occurred in both hemispheres; that the smooth-folded *timanica-polaris* lineage of the north is paired with the contemporaneous *Spiriferella* sp. of Western Australia, and that *S. keilhavii* was close to the contemporaneous *S. supplanta* of New Zealand, both having descended from *S. saranae*. *Spiriferella rajah* is found in both hemispheres, probably as a descendant from *S. supplanta*, and *S. pseudotibetana* of the north is similar to *S. australasica* from Western Australia.

Waterhouse (1971c) suggested that glacial episodes during the Permian Period would contract the width of the paleotropical belt, or biome, and lower its temperature, consequently increasing the chances of species and genera of one hemisphere to penetrate the tropical 'barrier'. *Spiriferella saranae*, *Spiriferella* sp. (aff. *S. wimani*, *S. polaris*) and *S. supplanta* all appeared in the Southern Hemisphere during cold episodes, but such examples for *Spiriferella* are few. The principal entry of *Elivina* into the Southern Hemisphere occurred during the Kungurian (Afghanistan) and Kalabaghian times (Himalayas, Timor), when cold episodes occurred (Waterhouse, 1973b) and also during the Sterlitamakian (cold) of Western Australia.

It may be noted also that *Spiriferella* and allies are absent from the Zechstein and Magnesian limestones of northern Europe, probably because they, like so many spiriferaceans, could not tolerate the high salinities. *Spiriferella* is absent also from the Phosphoria Group of Idaho, Wyoming, Montana, and other regions (Yochelson, 1968), probably because of peculiar geochemical conditions, though the stratigraphic occurrence of *Spiriferella scobina* (Meek) in Utah, presumably rare, remains to be clarified.

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APPENDICES 1-6

and

PLATES 1-8

Appendix 1

GSC LOCALITIES WITH *SPIRIFERELLA* AND *ALISPIRIFERELLA* SPECIES; with *Timaniella, Elivina, Eridmatus* and *Plicatospiriferella*

26406	*S. loveni, Timaniella*
46846	*S. leviplica*
52705	*Timaniella*
53259	*S. saranae*
53693	*Plicatospiriferella*
53703	*S. saranae*
53705	*S. saranae*
53706	*S. saranae*
53707	*S. saranae*
53709	*S. saranae*
53710	*S. saranae*
53712	*S. saranae*
53713	*S. saranae*
53714	*A. ordinaria*
53715	*S. saranae, A. ordinaria*
53720	*S. saranae*
53722	*S. saranae*
53725	*Plicatospiriferella*
53726	*Plicatospiriferella*
53813	*S. pseudodraschei*
53814	*S. pseudodraschei*
53818	*S. pseudodraschei*
53838	*Elivina*
53856	*S. saranae*
53860	*S. saranae*
53929	*S. keilhavii*
53931	*S. loveni*
53932	*S. loveni*
53939	*S. pseudotibetana*
53940	*S. pseudotibetana*
53944	*S. pseudotibetana*
53945	*S. pseudotibetana*
53995	*S. primaeva*
54000	*S. saranae, S. pseudodraschei*
54011	*S. saranae, S. pseudodraschei*
55136	*Eridmatus*
55137	*A. ordinaria*
56917	*S. saranae*
56920	*Eridmatus*
56925	*S. loveni*
56972	*S. saranae*
56977	*S. saranae*
56979	*S. loveni*
56985	*S. pseudotibetana*
56999	*S. saranae, A. ordinaria*
57044	*A. ordinaria*
57058	*S. pseudotibetana*
57062	*Plicatospiriferella*
57070	*S. primaeva*
57121	*S. pseudotibetana*
57141	*S. saranae*
57142	*S. yukonensis*
57143	*S. yukonensis*
57151	*S. pseudotibetana*
57152	*S. loveni*
57155	*S. yukonensis*
57242	*S. pseudotibetana*
57244	*S. loveni*
57259	*S. pseudotibetana*
57260	*S. pseudotibetana*
57273	*A. ordinaria*
57687	*S. loveni*
57720	*S. loveni*
58968	*A. gydanensis*
58973	*A. gydanensis, S. loveni, Timaniella*
58977	*S. keilhavii*
76029	*S. keilhavii*
C-1886	*S. loveni*
C-3993	*S. loveni*
C-3995	*A. gydanensis*
C-3996	*S. loveni*
C-4002	*S. loveni*
C-4004	*S. loveni*
C-4007	*S. keilhavii*
C-4014	*S. loveni*
C-4015	*S. loveni*
C-4016	*S. keilhavii, Timaniella*
C-4018	*S. pseudotibetana*
C-4019	*S. keilhavii, Timaniella*
C-4020	*S. loveni*
C-4021	*S. loveni*
C-4023	*S. keilhavii, Timaniella*
C-4024	*S. loveni*
C-4025	*S. loveni*
C-4026	*S. loveni*
C-4035	*S. loveni*
C-4054	*S. saranae*
C-4060	*S. loveni*
C-4061	*S. loveni*
C-4062	*S. pseudotibetana*
C-4063	*S. keilhavii*
C-4068	*S. leviplica*
C-4069	*S. leviplica*
C-4070	*S. leviplica*
C-4071	*S. leviplica*
C-4072	*S. loveni*
C-4073	*S. loveni*
C-4074	*S. leviplica*
C-4079	*S. saranae*
C-4080	*Timaniella*
C-4081	*S. keilhavii, Timaniella*
C-4095	*S. leviplica*
C-4229	*S. saranae*
C-4230	*S. saranae*
C-6136	*S. keilhavii*
C-6174	*S. vojnowskii*
C-6639	*S. loveni*
C-10904	*Timaniella*
C-10908	*A. gydanensis*
C-11868	*Timaniella*
C-47947	*S. ?keilhavii*

Appendix 2

DETAILS OF GSC LOCALITIES

GSC locality	GSC section	Page in Bamber (1972)	Formation	Stratigraphic position
				(m above base of formation unless otherwise indicated)
26406	Northern Grinnell Peninsula, Devon Is., Assistance Formation			
46846				
52705	116P-6		Unnamed sandstone unit	?347
53259	116O-7		Jungle Creek	Talus collection
53693	116H-1A		Ettrain	178
53703	116H-1A	96	Jungle Creek	41
53705	116H-1A	96	Jungle Creek	76 - 78
53706	116H-1A	95	Jungle Creek	124
53708	116H-1A		Jungle Creek	134
53709	116H-1A	95	Jungle Creek	179
53710	116H-1A	95	Jungle Creek	185
53712	116H-1A	95	Jungle Creek	187
53713	116H-1A	94	Jungle Creek	201
53714	116H-1A	94	Jungle Creek	206
53715	116H-1A	94	Jungle Creek	211
53720	116H-1B	102	Jungle Creek	40

Appendix 2 (continued)

GSC locality	GSC section	Page in Bamber (1972)	Formation	Stratigraphic position
53722	116H-1B	102	Jungle Creek	32
53725	116H-1B		Eastern equivalent of Ettrain	Top of formation
53726	116H-1B		Eastern equivalent of Ettrain	305
53813	116H-17	114	Jungle Creek	10 above base of incomplete section
53814	116H-17	114	Jungle Creek	14 above base of incomplete section
53818	116H-17	112	Jungle Creek	Upper part of formation, 54 - 57 above base of incomplete section
53838	116P-11	145	Unnamed shale unit	518 (talus)
53841	116P-11	144	Unnamed sandstone unit	659
53856	116P-10	140	Unnamed carbonate unit	46 - 48
53860	116P-10	139	Unnamed carbonate unit	98
53929	116C-1	9	Tahkandit	?148
53931	116C-1	9	Tahkandit	287 below top of formation
53932	116C-1	9	Tahkandit	?113
53939	116C-1 64°58'30"N, 140°54'W		Tahkandit	96
				(m above base of formation unless otherwise indicated)
53940	116C-1 64°58'30"N, 140°54'W		Tahkandit	96
53944	116C-1 64°58'30"N, 140°54'W		Tahkandit	82
53945	116C-1		Tahkandit	79
53995	116F-9	35	Jungle Creek	158
54000	116F-9	32	Jungle Creek	520 - 527
54011	116P-10	141	Unnamed basal sandstone unit	Talus from base of Permian
55136	65°52'N, 136°10'W		Jungle Creek	Spot locality
55137	65°52'N, 136°10'W		Jungle Creek	Spot locality
56917	116C-2		Tahkandit	0 - 0.6
56920	116C-2	16	Jungle Creek	152 - 155
56925	116C-2	10	Tahkandit	99
56972	116F-16	55	Jungle Creek	649
56977	116F-16	55	Jungle Creek	658
56979	116C-2	10	Tahkandit	103
56985	116C-2	11	Tahkandit	87
56999	116F-16	56	Jungle Creek	630
57044	116C-2	16	Jungle Creek	159 - 161
57058	116C-2	11	Tahkandit	87
57062	116C-2		Western equivalents of Ettrain	289 - 290 below top of formation
57070	116C-2		Western equivalents of Ettrain	43 below top of formation
57121	116C-2	11	Tahkandit	23
57141	116F-16	55	Jungle Creek	637
57142	116F-16	62	Jungle Creek	35
57143	116C-2	18	Jungle Creek	125
57151	116C-2	11	Tahkandit	82
57152	116C-2	10	Tahkandit	103
57155	116C-2	18	Jungle Creek	125
57242	116C-2	11	Tahkandit	23 - 26
57244	116C-2	10	Tahkandit	103
57259	116C-2	11	Tahkandit	23 - 24
57260	116C-2	11	Tahkandit	36
57273	116C-2	16	Jungle Creek	170

GSC locality	Location	Formation	Stratigraphic position
57687	11 km east of East Cape, Cañon Fiord, Ellesmere Island	Trold Fiord	18 m above base of formation
57720	Great Bear Cape, Bjorne Peninsula, Ellesmere Island	Degerböls	
58968	Northeast coast of Cañon Fiord, Ellesmere Island	Assistance	
58973	Northeast coast of Cañon Fiord, Ellesmere Island	Assistance	
58977	Great Bear Cape, Ellesmere Island	Degerböls	talus
76029	6 km northwest of Cape Fortune, Cameron Island	Assistance	
C-1886	12 km northwest of Yelverton Pass summit, Ellesmere Island	Trold Fiord	
C-3993	Creek, southwest side of Mount Bridgman, Ellesmere Island; 79°52'N, 82°55'W	Degerböls	
C-3995	As above	Trold Fiord	47 m above base
C-3996	As above	Trold Fiord	161 m above base
C-4002	79°30'N, 83°25'W	Assistance	
C-4004	79°30'N, 83°25'W	Trold Fiord	
C-4007	Stream northwest of major drainage, 4 km north of Oesle Fiord, Ellesmere Island	Assistance	
C-4014	80°05'N, 81°45'W	Trold Fiord	
C-4015	80°05'N, 81°45'W	Trold Fiord	
C-4016	80°05'N, 81°45'W	Assistance	
C-4018	80°05'N, 81°45'W	Belcher Channel	
C-4019	80°05'N, 81°45'W	Assistance	
C-4020	80°05'N, 81°45'W	Trold Fiord	
C-4021	80°05'N, 81°45'W	Trold Fiord	
C-4023	80°05'N, 81°45'W	Assistance	
C-4024	80°05'N, 81°45'W	Assistance	
C-4025	80°05'N, 81°45'W	Assistance	
C-4026	80°05'N, 81°45'W	Trold Fiord	
C-4035	33 km southeast of Cape Lockwood, Ellesmere Island; 80°12'N, 81°30'W	Tanquary	49 m from top
C-4054	9.3 km south of Peak 3550, west of Trold Fiord, north of Blind Fiord, Raanes Peninsula, Ellesmere Island; 78°31'N, 85°25'W	Assistance	talus at base
C-4060	As above	Assistance	152 (talus)
C-4061 - C-4063	As above	Unnamed formations	
C-4068 - C-4071	8 km south of head of Blind Fiord, Ellesmere Island, west side	van Hauen	
C-4072 - C-4074	5 km north of head of Blind Fiord, Ellesmere Island	van Hauen	
C-4079	8 km southwest of head of Trold Fiord, Ellesmere Island	Belcher Channel	
C-4080, C-4081	As above	Assistance	
C-4095	Section between Mount Schuchert, Mount Barrell, Krieger Mountains, Ellesmere Island	Degerböls	
C-4229	68°15'N, 136°26'W, Yukon Territory	Unnamed Permian clastics	
C-4230	68°15'N, 136°26'W, Yukon Territory	Unnamed Permian clastics	
C-6136	Upper Cache Creek, Yukon Territory; NTS 117A,68°07'30"N, 136°22'W	Unnamed formation, coeval with Saddler-rochit Fm.	
C-6639	Blow River area, south of Cottonwood Creek, Yukon Territory	Unnamed crinoidal grainstone	
C-6174	North-trending ridge at headwaters of Kandik River; 65°48'N, 120°21'W	Jungle Creek	
C-10904	68°01'N, 136°36'W	Unnamed Permian clastics	
C-10908	White Mountains. Fault slice on north flank of White Uplift; 68°01'N, 136°36'W	Unnamed Permian carbonate	
C-11868	Divide between headwaters of Gravel and Timber creeks, north flank of Old Crow Basin	Saddlerochit	
C-47947	77°36'N, 86°10'W	Talus, Degerböls eastern Bjorne Peninsula	

Appendix 3

LOCATION OF SECTIONS, GEOLOGICAL SURVEY OF CANADA

Section	Location	Airphoto
From Bamber and Waterhouse (1971)		
116C-1	64°58'30"N, 140°54'W	A13784-39
116C-2	64°58'30"N, 140°54'W	A13784-39
116F-9	65°23'N, 140°40'W	A13138-232
116F-16	65°17'30"N, 140°42'30"W	A13138-234
116G-9	65°48'30"N, 138°55'W	A14451-103
116H-1A	65°53'N, 136°08'W	A13137-68
116H-1B	65°53'N, 136°05'30"W	A14368-83
116P-6	67°58'30"N, 136°24'30"W	A14361-14
116P-10	67°31'N, 136°32'30"W	A14368-19
116P-11	67°41'N, 136°18'W	A14361-68
From Nelson and Johnson (1968)		
1	65°53'N, 136°13'W	
2	65°53'N, 136°10'W and downstream	
3	65°12'N, 140°39'W	
6	65°49'30"N, 138°55'W	
7	67°32'N, 136°26'W	

Appendix 4

J.B. WATERHOUSE COLLECTIONS FROM THE YUKON TERRITORY

Loc.	Area	Section	Figure	Zone	Species
2	Ettrain Creek	Ridge north of 116F-16	7	Ej	*S. pseudodraschei*
9	Ettrain Creek	Ridge north of 116F-16	7	Ey	*S. saranae*
13	Ettrain Creek	Ridge north of 116F-16	7	Ey	*S. pseudodraschei*
19	Ettrain Creek	Ridge north of 116F-16	7	Eka	*Er. petita*
27	Ettrain Creek	Ridge north of 116F-16	7	Eta	*Er. petita*
54	Ettrain Creek	Ridge north of 116F-16	7	Ey	*S. pseudodraschei*
58	Ettrain Creek	Ridge north of 116F-16	7	Ey	*S. pseudodraschei*
59	Ettrain Creek	Ridge north of 116F-16	7	Ey	*S. pseudodraschei*
63	Ettrain Creek	Ridge north of 116F-16	7	Ey	*S. pseudodraschei*
64	Ettrain Creek	Ridge north of 116F-16	7	Ey	*S. pseudodraschei*
67	Ettrain Creek	Ridge north of 116F-16	7	E	*S. saranae*
70	Ettrain Creek	Ridge north of 116F-16	7	E	*S. pseudodraschei*
88	Ettrain Creek	Ridge southwest of 116F-16	7	Ey	*S. pseudodraschei*
89	Ettrain Creek	Ridge southwest of 116F-16	7	Ey	*S. pseudodraschei*
90	Ettrain Creek	Ridge southwest of 116F-16	7	Ey	*S. pseudodraschei*
109	Ettrain Creek	116F-9	6	Ey	*S. pseudodraschei*
110	Ettrain Creek	116F-9	6	Ey	*S. pseudodraschei*
111	Ettrain Creek	West of 116F-16	7	Ey	*S. saranae*
113	Ettrain Creek	116F-9	6	Ey	*S. saranae*
127	Ettrain Creek	Saddle 1 km south of 116F-9	6	Eta	*Er. petita*
135	Ettrain Creek	Saddle 1 km south of 116F-9	6	Eta	*Er. petita*
142	Ettrain Creek	116F-9	6	D	*S. yukonensis*
145	Ettrain Creek	116F-9	6	D	*S. yukonensis*
149	Ettrain Creek	116F-9	6	D	*S. yukonensis*
160	Ettrain Creek	116F-9	6	?Cgb	*S. yukonensis*
217	Peel River	116H-1B	4	Cp	*P. gjeliensis*
226	Peel River	South bank, opposite 116H-1A	3	Cp	*S. primaeva*
227	Peel River	South bank, opposite 116H-1A	3	Cp	*S. primaeva*
229	Peel River	116H-1A	3	Ea	*A. ordinaria*
232	Peel River	116H-1A	3	Ey	*S. saranae*
442	Ettrain Creek	Between 116F-9 and -16	6	Dk	*S. yukonensis*
443	Ettrain Creek	Midway between 116F-9 and -16	7	D	*S. yukonensis*
505	Ettrain Creek	Ridge southwest of 116F-16	7	Ey	*S. pseudodraschei*
506	Ettrain Creek	Ridge southwest of 116F-16	7	Ey	*S. pseudodraschei*
508	Ettrain Creek	Ridge southwest of 116F-16	7	Ey	*S. saranae*
519	Tatonduk River			E	*S. pseudotibetana*
526	Ettrain Creek	Ridge southwest of 116F-16	7	Ej	*S. pseudodraschei*

Appendix 4 (continued)

Loc.	Area	Section	Figure	Zone	Species
537	Ettrain Creek	Ridge west of 116F-16	7	Ej	*S. pseudodraschei*
541	Ettrain Creek	Ridge north of 116F-16	7	Ey	*S. pseudodraschei*
542	Ettrain Creek	Ridge north of 116F-16	7	Et	*S. pseudodraschei*
543	Ettrain Creek	Ridge north of 116F-16	7	Et	*S. pseudodraschei*
544	Ettrain Creek	Ridge north of 116F-16	7	Ej	*S. pseudodraschei*
545	Ettrain Creek	Ridge north of 116F-16	7	Ej	*S. pseudodraschei*
546	Ettrain Creek	Ridge north of 116F-16	7	Ej	*S. pseudodraschei*
554	Ettrain Creek	Ridge north of 116F-16	7	Ey?	*S. pseudodraschei*
555	Ettrain Creek	Ridge north of 116F-16	7	?Ey	*S. pseudodraschei*
556	Ettrain Creek	Ridge north of 116F-16	7	E	*S. pseudodraschei*
558	Ettrain Creek	Ridge north of 116F-16	7	Ej	*S. saranae*
592	Ettrain Creek	Near overthrust, between 116F-16 and 116F-9	6	D	*S. yukonensis*
612	Ettrain Creek	116F-16	7	D	*S. yukonensis*
802	Ettrain Creek	Ridge 4 km east of 116F-9 (east of area mapped in Figure 7)		D	*S. yukonensis*
989	Ettrain Creek	116F-16	7	D	*S. yukonensis*
990	Ettrain Creek	116F-16	7	D	*S. yukonensis*
993	Ettrain Creek	116F-9	6	Eka	*Er. petita*
994	Ettrain Creek	116F-9	6	Eka	*Er. petita*
995	Peel River	116H-1B	4	Cp	*S. primaeva*
996	Ettrain Creek	116F-16	7	Eo	*Er. petita*
998	Ettrain Creek	116F-9	6	Dk	*S. yukonensis*
999	Ettrain Creek	116F-9	6	Cgb	*S. primaeva*

Appendix 5

GSC SPECIMENS MENTIONED IN TEXT

13767*	*S. loveni*	35501* - 5	*Er. petita*
26427	*T. harkeri*	(35501,*, 35502*)	
26855*	*P. canadensis*	35507 - 10	*Er. petita*
26944	*S. saranae*	35512	*Er. petita*
26945*	*S. saranae*	35513 - 4	*A. ordinaria*
26946	*S. saranae*	35516 - 78	*S. pseudodraschei*
26949	*S. pseudodraschei*	(35521,*, 35529*)	
26950	*S. saranae*	35567*)	
26960	*A. ordinaria*	35581	*S. pseudodraschei*
26962 - 3	*A. ordinaria*	35582 - 35622	*S. saranae*
27003	*S. pseudotibetana*	35623 - 4	*S. saranae*
27014	*S. loveni*	35625	*S. pseudotibetana*
27040	*S. keilhavii*	35626	*S. loveni*
27034	*E. cordiformis*	35627	*S. loveni*
30741* - 6	*S. yukonensis*	35628 - 9	*S. loveni*
(30742,* 30744*)		35630 - 38	*S. pseudotibetana*
30747 - 56*	*A. ordinaria*	35640 - 41	*S. pseudotibetana*
(30752,* 30755*)		35642	*S. loveni*
30758 - 9*	*S. pseudodraschei*	35643	*S. loveni*
30761*	*S. pseudodraschei*	35644 - 49	*S. keilhavii*
30763*	*S. saranae*	35650	*S. loveni*
30765*	*S. saranae*	35651 - 66	*S. keilhavii*
30766*	*S. loveni*	35670 - 76	*S. loveni*
30767*	*S. saranae*	35677	*S. keilhavii*
30768 - 69	*S. saranae*	35678 - 81	*S. loveni*
30770*	*S. pseudodraschei*	35682	*S. keilhavii*
30771 - 3	*S. pseudotibetana*	35683 - 85	*S. loveni*
30774	*S. loveni*	35686	*S. loveni*
30775	*S. keilhavii*	35687 - 90	*S. loveni*
30777*	*S. keilhavii*	35691	*S. keilhavii*
30781*	*S. keilhavii*	35693 - 35715	*S. loveni*
30782*	*S. loveni*	35716	*S. keilhavii*
30785* - 6*	*S. loveni*	35717	*S. loveni*
30789* - 93*(30792*)	*S. loveni*	35718 - 21	*S. pseudotibetana*
30794*	*S. keilhavii*	35722* - 3*	*S. yukonensis*
30795	*S. loveni*	35724 - 26	*S.* cf. *vojnowskii*
30797*	*E. cordiformis*	35727	*S. keilhavii*
30798 - 30801	*S. leviplica*	35728 - 31	*A. gydanensis*

Appendix 5 (continued)

30802 - 5*	*S. keilhavii*	35733	*S. pseudotibetana*
30806* - 11(30807*)	*T. harkeri*	35734	*T. harkeri*
30812*	*S. keilhavii*	35735 - 36	*S. pseudotibetana*
35473 - 4*	*S. yukonensis*	35737	*S. keilhavii*
35475 - 8	*S. primaeva*	35738	*S. loveni*
35479*	*S. canadensis*	35739 - 40	*T. harkeri*
35480	*S. yukonensis*	35741 - 2	*S. pseudodraschei*
35482 - 5	*S. yukonensis*	35776	*S. loveni*
35486 - 95	*S. yukonensis*	35777	*P. canadensis*
35497 - 9	*Er. petita*	37073 - 4	*P. canadensis*
		37078 - 9	*P. canadensis*

* See figures in text.

Appendix 6

ROYAL ONTARIO MUSEUM SPECIMENS
MENTIONED IN THE TEXT

ROM number	Locality	Species
28204	JBW 226	*S. primaeva*
28205	JBW 145	*S. yukonensis*
28206	JBW 226	*S. primaeva*
28207	JBW 145	*S. yukonensis*
28209	JBW 89	*S. pseudodraschei*
28211	JBW 89	*S. pseudodraschei*
28212	JBW 89	*S. pseudodraschei*
28217	JBW 89	*S. pseudodraschei*
28219	JBW 242	*S. yukonensis*
28221	JBW 89	*S. pseudodraschei*

PLATE 1

Spiriferella primaeva n. sp.

Figures 1, 2, 5. Ventral, posterior and lateral views (all x2), holotype, GSC 35475 from JBW loc. 227, Ettrain equivalent, Peel River.

Figures 3, 4, 6. Ventral micro-ornament (x4), ventral exterior (x1), and ventral internal mould (x1), ROM 28204 from JBW loc. 226, Ettrain equivalent, Peel River.

Plicatospiriferella canadensis n. gen., n. sp.

Figure 7. Ventral valve (x1), GSC 35479 from JBW loc. 217, Ettrain equivalent, Peel River.

Figures 8-10. Holotype, ventral, dorsal and lateral views (x2), GSC 26855 from GSC loc. 53726, Ettrain equivalent, Peel River.

Spiriferella yukonensis n. sp.

Figures 11, 12. Dorsal and ventral views, holotype, ROM 28205 (x1) from JBW loc. 145, new formation, Ettrain Creek area.

Figure 13. Ventral view, GSC 35722 (x1) from GSC loc. 57142, Ettrain Creek.

Figure 14. Lateral view, ventral valve, GSC 30744 (x1) from GSC loc. 57143, basal Jungle Creek Formation, Tatonduk River.

Figure 15. Ventral view (x1), GSC 35723 from GSC loc. 57142, new formation, Ettrain Creek.

Figure 16. Dorsal view, ROM 28219 (x1) from JBW loc. 442, new formation, Ettrain Creek area.

Figures 17, 18. Ventral and lateral views, GSC 30742 (x1) from GSC loc. 57155, Jungle Creek Formation, Tatonduk River.

Figure 19. Ventral internal mould (x1), GSC 30746 from GSC loc. 57155, Jungle Creek Formation, Tatonduk River.

Figure 20. Ventral ornament (x4), GSC 30745 from same locality as fig. 19.

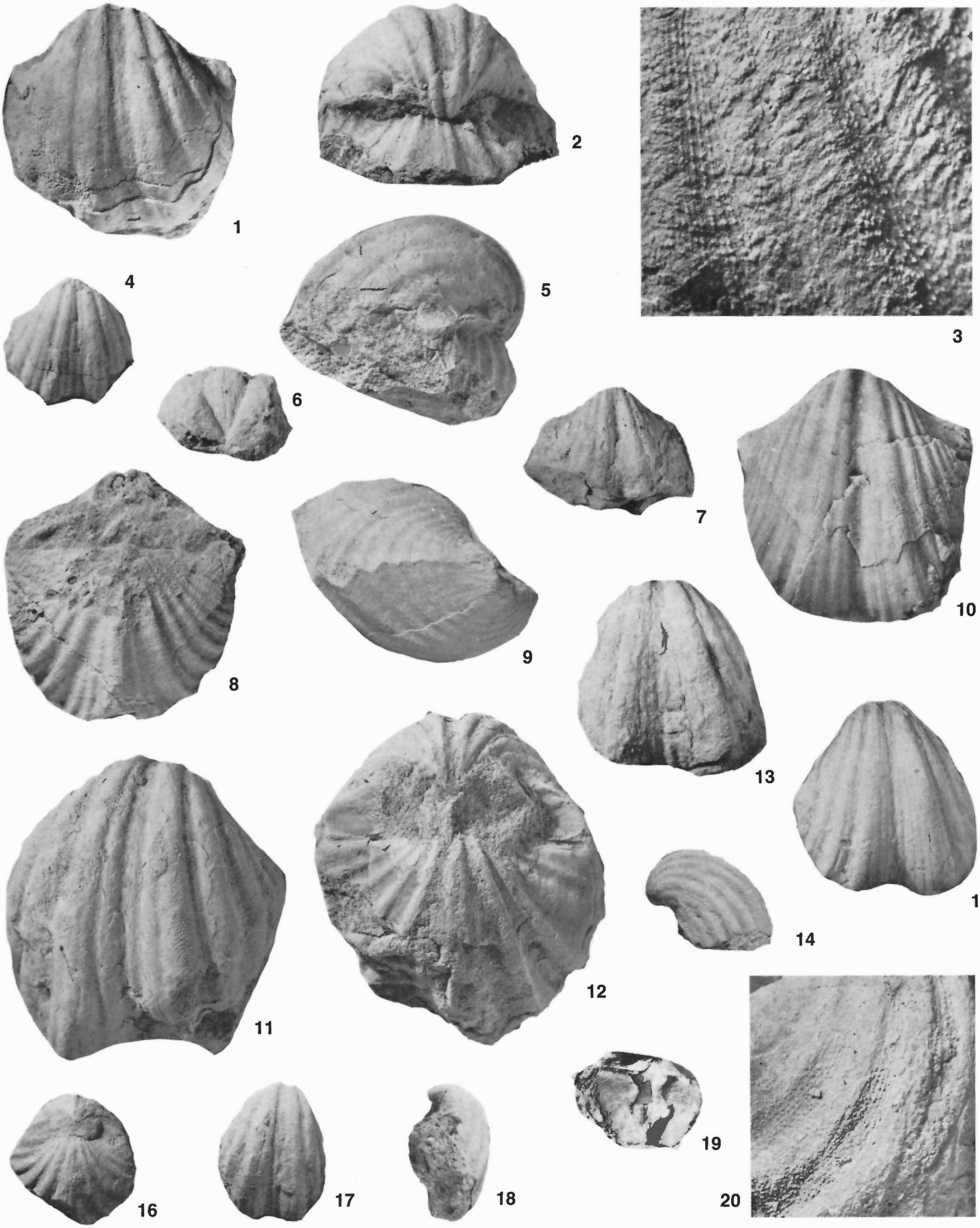
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PLATE 2

Eridmatus petita n. sp.

Figure 1. Ventral view (x2), latex cast of GSC 35507 with other specimens, from JBW loc. 135, Jungle Creek Formation, Ettrain Creek area.

Figure 2. Ventral view (x1), holotype GSC 35502 from JBW loc. 19, Jungle Creek Formation, Ettrain Creek area.

Figure 3. Ventral view, GSC 35510 (x1) from GSC loc. 56920, Jungle Creek Formation, Tatonduk River.

Figure 4. Ventral view, topotype, GSC 35499 and other shells (x1) from JBW loc. 19, Jungle Creek Formation, Ettrain Creek area.

Figure 5. Ventral view, latex cast of GSC 35508 (left) and 35509 (x1) from JBW loc. 135, Jungle Creek Formation, Ettrain Creek area.

Figure 6. Dorsal view (x2), GSC 35505 from JBW loc. 19, Jungle Creek Formation, Ettrain Creek area.

Alispiriferella ordinaria (Einor) n. gen.

Figures 7, 8. Dorsal and ventral views, GSC 26960 (x1) from GSC loc. 53714, Jungle Creek Formation, Peel River.

Figures 9, 12. Ventral internal mould, GSC 26962 (x1) from GSC loc. 53715, Jungle Creek Formation, Peel River.

Figures 10, 11. Ventral and dorsal views, GSC 30753 (x1) from GSC loc. 55137, unnamed beds, Ogilvie Mountains.

Figure 13. Ventral view of GSC 30749 (x1) from same locality as figs. 10, 11.

Spiriferella pseudodraschei Einor

Figure 14. Internal mould of ventral valve, GSC 35741 (x1) from JBW loc. 505, Jungle Creek Formation, Ettrain Creek area.

Figure 15. Ventral valve, GSC 30759 (x1) from GSC loc. 54011, unnamed beds, Richardson Mountains.

Figure 16. Latex cast of dorsal exterior, GSC 35521 (x2) from JBW loc. 88, Jungle Creek Formation, Ettrain Creek area.

Figure 17. Internal mould of ventral valve, GSC 35520 (x2), same locality as fig. 16.

Figure 18. Tilted posterior view, latex mould, GSC 35567 (x1) from JBW loc. 555, Jungle Creek Formation, Ettrain Creek area.

Figure 19. Dorsal view, internal mould, GSC 35537 (x1) from JBW loc. 58, Jungle Creek Formation, Ettrain Creek area.

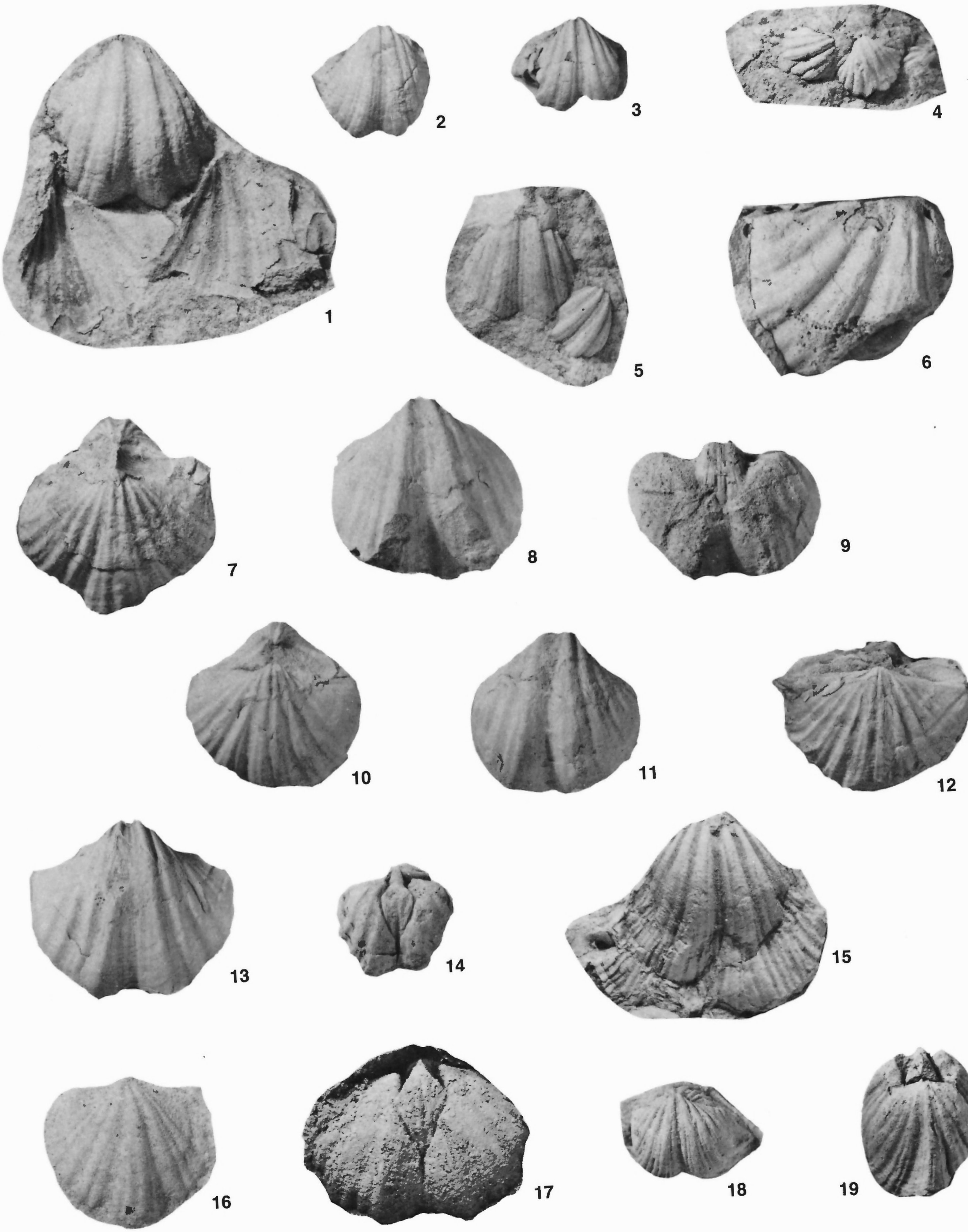
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PLATE 3

(All specimens from Jungle Creek Formation, Ettrain Creek area, northern Ogilvie Mountains)

Spiriferella pseudodraschei Einor

Figures 1, 2. Ventral and dorsal views of internal mould, GSC 35525 (x2) from JBW loc. 89.

Figures 3, 4. Ventral and dorsal views of internal mould, GSC 35553 (x2) from JBW loc. 543.

Figure 5. Latex cast of ventral valve, GSC 35568 (x2) from JBW loc. 505.

Figure 6. Dorsal aspect of latex cast, GSC 35571 (x2) from JBW loc. 2.

Figure 7. Dorsal valve, GSC 35529 (x2) from JBW loc. 89.

Figures 8, 10. Ventral and dorsal aspects of internal mould, GSC 35524 (x2) from same locality as fig. 7.

Figure 9. Latex cast of external ventral valve, GSC 35567 (x2) from JBW loc. 555, Ettrain Creek area.

Figure 11. Internal mould of ventral valve, ROM 28221 (x4) from JBW loc. 89.

Figure 12. Latex cast of interior of ventral valve, GSC 35742 (x2) from same locality as fig. 11.

Figure 13. Latex cast of interior of ventral valve, GSC 35530 (x2) from same locality as fig. 11.

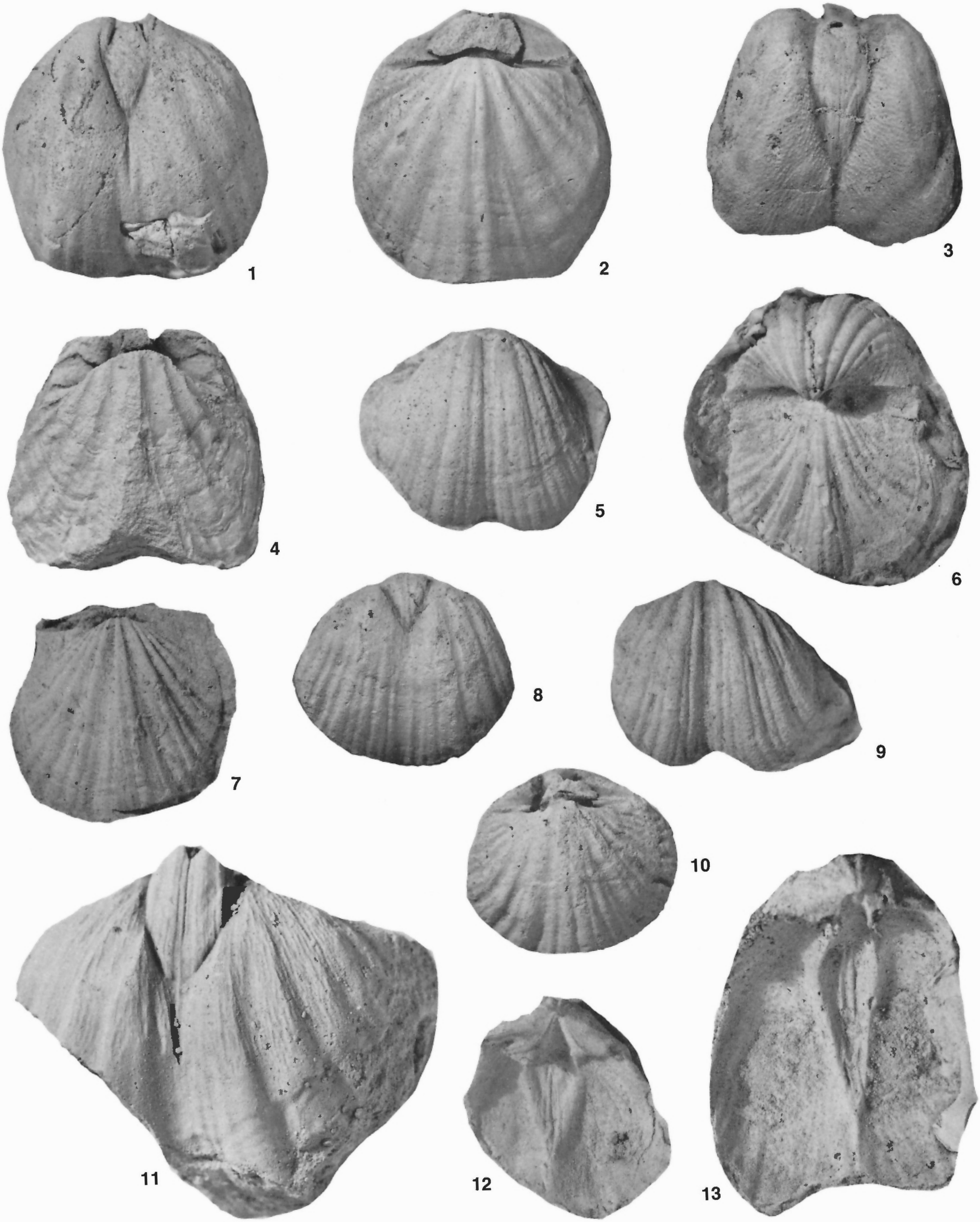
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PLATE 4

Spiriferella saranae (de Verneuil)

Figures 1, 2. Ventral and dorsal views, GSC 30765 (x1) from GSC loc. 53713, Jungle Creek Formation, Peel River.

Figure 3. Dorsal view, GSC 35591 (x1) from GSC loc. 53709, Jungle Creek Formation, Peel River.

Figure 4. Internal aspect of ventral valve, GSC 35603 (x1) from GSC loc. 57141, Jungle Creek Formation, Ettrain Creek area.

Figure 5. Ventral view, GSC 30768 (x1) from GSC loc. 53712, Jungle Creek Formation, Peel River.

Figure 6. Ventral view, GSC 26950 (x2) from GSC loc. 53713, Jungle Creek Formation, Peel River.

Figures 7, 8. Posteroventral view of internal mould (x1, x4), GSC 30769 from GSC loc. 53707, Jungle Creek Formation, Peel River.

Figure 9. Ventral valve, GSC 35601 (x1) from GSC loc. 54011, unnamed beds, Richardson Mountains.

Figure 10. Ventral valve, GSC 35617 (x1) from GSC loc. 56999, Jungle Creek Formation, Ettrain Creek area.

Figure 11. Ventral internal mould, GSC 35620 (x1) from JBW loc. 558, Jungle Creek Formation, Ettrain Creek area.

Spiriferella pseudotibetana Stepanov

Figure 12. Dorsal valve, GSC 35636 (x2) from GSC loc. 57242, Tahkandit Formation, Tatonduk River.

Figure 13. Ventral valve, GSC 30773 (x1) from GSC loc. 57259, Tahkandit Formation, Tatonduk River.

Figure 14. Ventral internal mould, GSC 35735 (x1) from JBW loc. 519, Tahkandit Formation, Tatonduk River.

Figure 16. Ventral micro-ornament, GSC 35736 (x2) from GSC loc. 57242, Tahkandit Formation, Tatonduk River.

Figure 17. Ventral view, GSC 30771 (x2) from GSC loc. C-4018, Belcher Channel Formation, Ellesmere Island.

Spiriferella keilhavii? (von Buch)

Figure 15. Ventral view, GSC 35737 (x1) from GSC loc. C-47947, Degerbols Formation, Ellesmere Island.

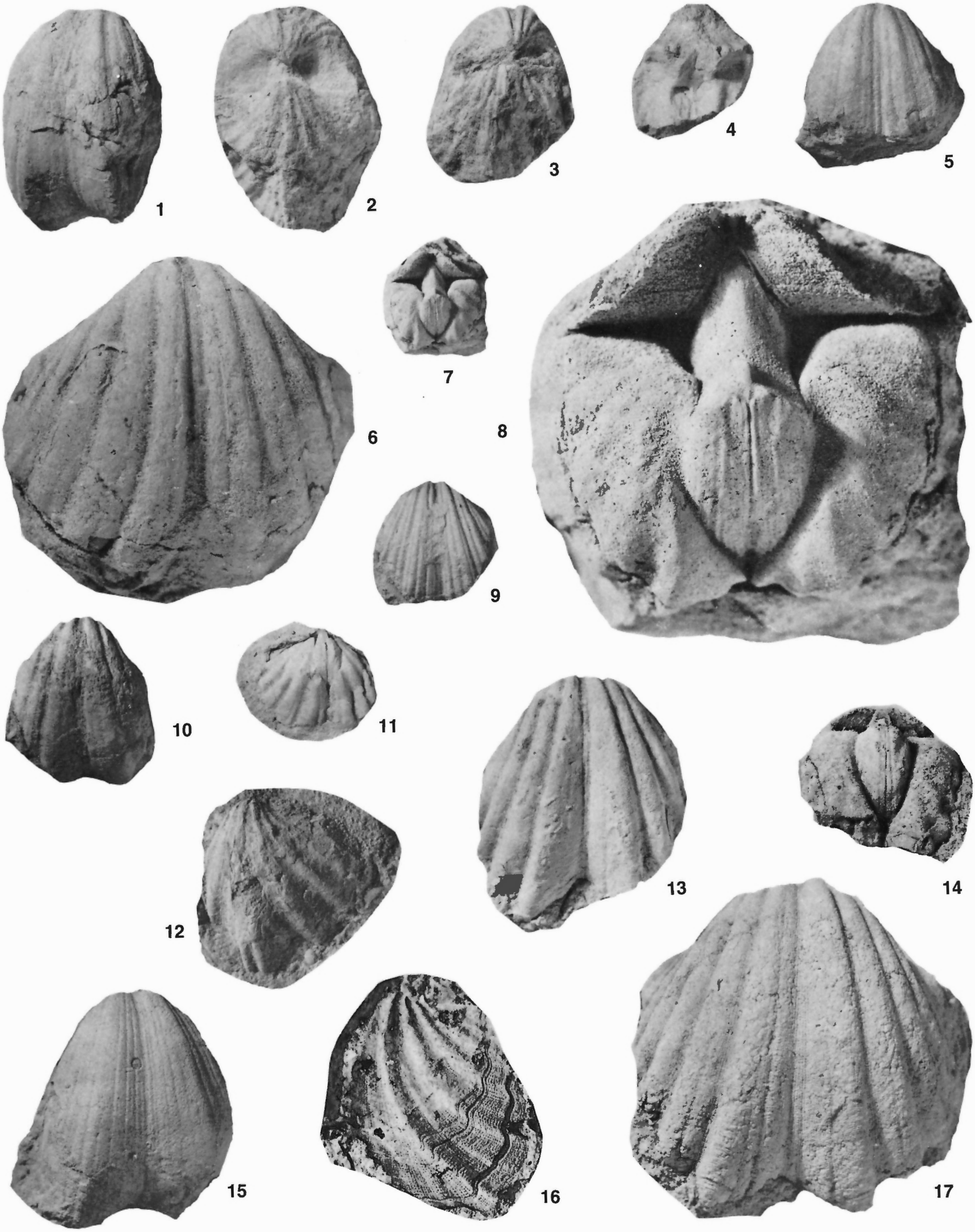
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PLATE 5

Spiriferella pseudotibetana Stepanov

Figure 1. Ventral view, GSC 30772 (x1) from GSC loc. 57058, Tahkandit Formation, Tatonduk River.

Spiriferella loveni (Diener)

Figure 2. Ventral view, GSC 35626 (x1) from GSC loc. 26406, Assistance Formation, Devon Island.

Figures 3 - 5. Lateral (tilted), internal and external views, ventral valve, GSC 30789 (x1) from GSC loc. 26406, Assistance Formation, Devon Island.

Figure 6. Ventral interior, GSC 30791 (x1) from same locality as figs. 3 - 5.

Figures 7, 8. Dorsal view (x2), and interior view (x1) showing spiralia, GSC 30795 from same locality as figs. 3 - 5.

Figure 9. Ventral internal mould, GSC 35700 (x1) from GSC loc. C-6639, unnamed beds, Richardson Mountains.

Figures 10, 11. Dorsal and ventral views, GSC 35704 (x1) from GSC loc. 57244, Tahkandit Formation, Tatonduk River.

Figure 12. Ventral micro-ornament, GSC 35706 (x2) from same locality as figs. 10, 11.

Figure 13. Ventral micro-ornament, GSC 35738 (x2) from same locality as figs. 10, 11.

Figure 14. Dorsal view, GSC 35693 (x1) from GSC loc. 26406, Assistance Formation, Devon Island.

Figures 15 - 17. Ventral, anterior (dorsal valve on top) and dorsal views of GSC 30786 (x1) from GSC loc. C-4024, Assistance Formation, Ellesmere Island.

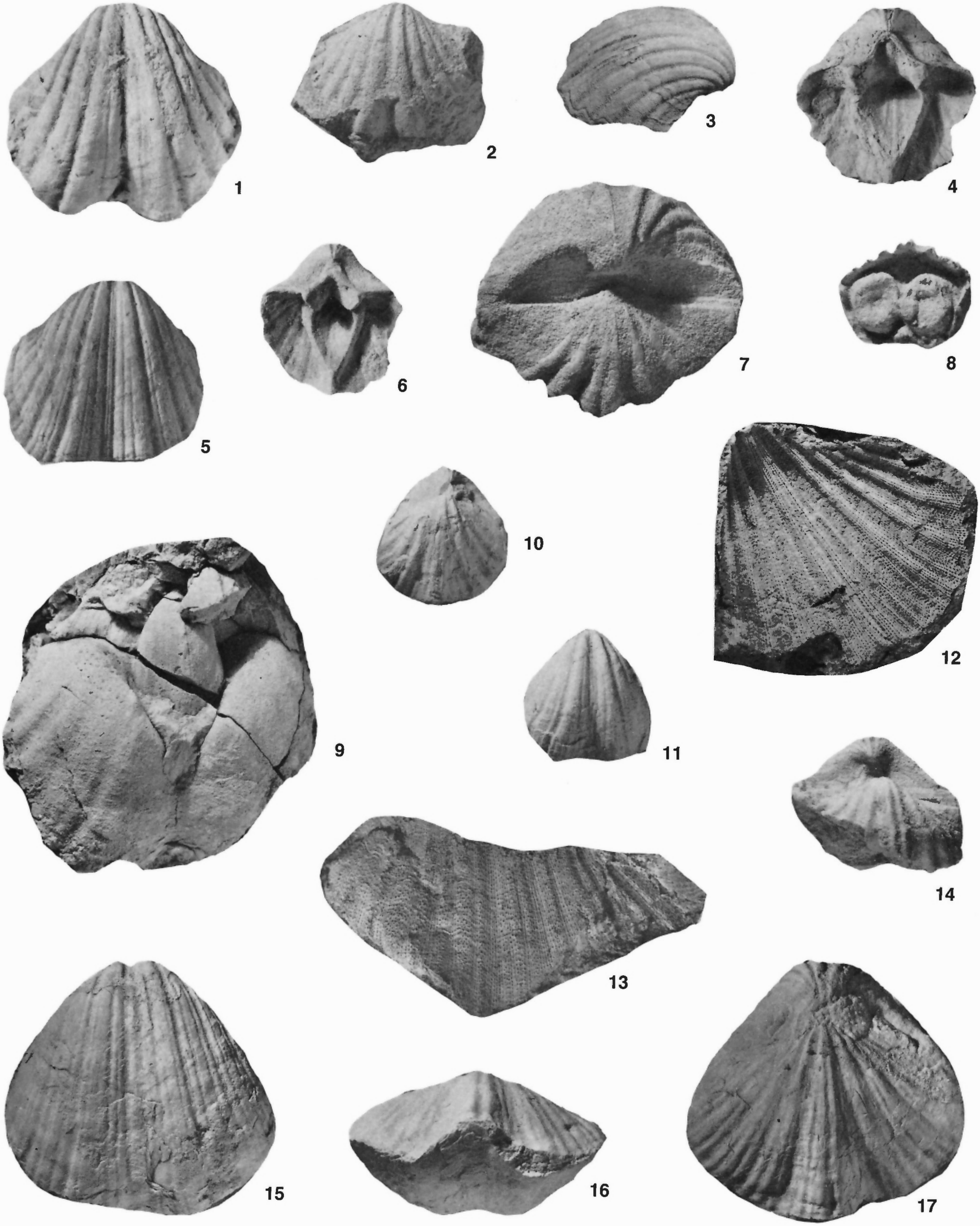
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PLATE 6

Spiriferella loveni (Diener)

Figure 1. Dorsal view, GSC 35689 (x1) from GSC loc. 58973, Assistance Formation, Ellesmere Island.

Figure 2. Ventral exterior, GSC 35676 (x1) from GSC loc. C-4015, Trold Fiord Formation, Ellesmere Island.

Spiriferella keilhavii (von Buch)

Figures 3, 4. External and internal views, ventral valve, GSC 35727 (x1) from GSC loc. 76029, Trold Fiord Formation, Cameron Island.

Figures 5-7. Dorsal, ventral and lateral views of GSC 35653 (x1) from GSC loc. C-4081, Assistance Formation, Ellesmere Island.

Figures 8, 9, 14. Lateral, ventral and dorsal views, GSC 30775 (x1) from GSC loc. 76029, Trold Fiord Formation, Cameron Island.

Figures 10, 11. Ventral and dorsal views of GSC 35645 (x1) from GSC loc. C-4016, Assistance Formation, Ellesmere Island.

Figure 12. Ventral valve, GSC 30803 (x1) from GSC loc. C-6136, unnamed beds, Richardson Mountains.

Figure 13. Dorsal valve, GSC 35677 (x1) from GSC loc. C-4016, Assistance Formation, Ellesmere Island.

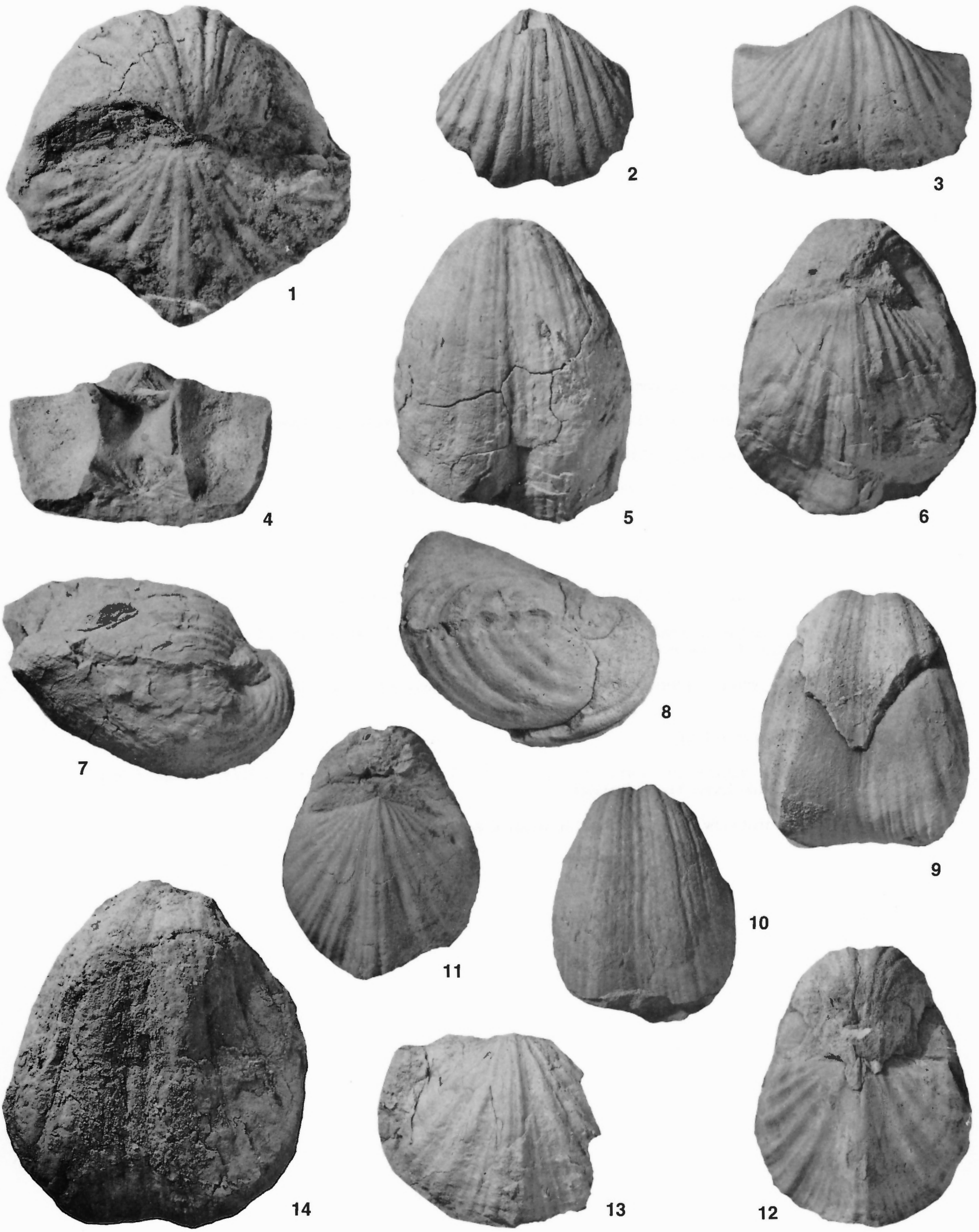
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PLATE 7

Alispiriferella gydanensis (Zavodowsky)

Figure 1. Ventral valve, GSC 35729 (x2) from GSC loc. 58968, Assistance Formation, Ellesmere Island.

Figure 2. Dorsal view, GSC 35731 (x1) from same locality as fig. 1.

Figure 3. Ventral valve, GSC 35730 (x2) from same locality as fig. 1.

Figure 4. Dorsal view, GSC 35728 (x1) from same locality as fig. 1.

Spiriferella leviplica n. sp.

Figure 5. Ventral view, GSC 30801 (x1) from GSC loc. C-4095, Degerbols Formation, Ellesmere Island.

Figures 6-8. Ventral, lateral and dorsal views, holotype, GSC 30799 (x1) from GSC loc. C-4074, van Hauen Formation, Ellesmere Island.

Figures 9-11. Ventral internal mould (x2), cardinal process (x4), GSC 30798 from same locality as figs. 6-8.

Spiriferella vojnowskii Ifanova

Figures 12, 13. Ventral and dorsal views, GSC 35726 (x1) from GSC loc. C-6174, ?Jungle Creek Formation, Kandik River, Yukon Territory.

Figure 14. Ventral view, GSC 35725 (x1) from same locality as figs. 12, 13.

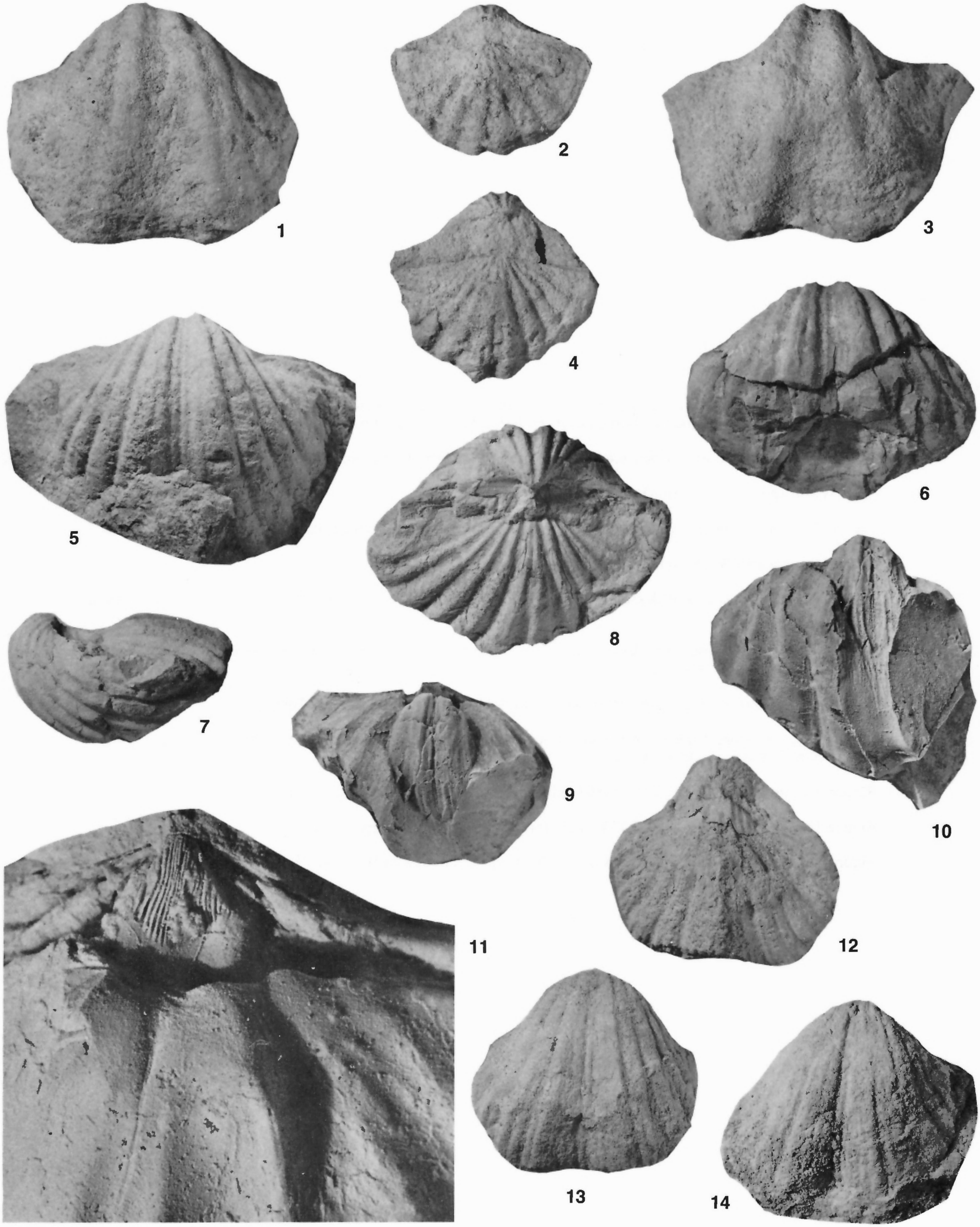
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PLATE 8

Elivina cordiformis n. sp.

Figures 1 - 5. Dorsal (x1, x2), ventral (x1), lateral (x2) and anterior (x1) views, holotype, GSC 27034 from GSC loc. 53838, unnamed beds, northern Richardson Mountains.

Figures 6, 7. Ventral and dorsal views, paratype, GSC 30797 (x1) from same locality as figs. 1 - 5.

Spiriferella arctica (Haughton)

Figure 8. Cast of ventral valve (x1), lectotype, M'Clintock collection, National Museum, Dublin, Eire.

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Figures 9, 11. Ventral and dorsal views, GSC 30808 (x1) from GSC loc. 26406, Assistance Formation, Devon Island.

Figures 10, 12. Ventral and dorsal views of internal mould, GSC 35740 (x1) from GSC loc. 52705, unnamed beds, White Mountains.

Figure 13. Dorsal interior, GSC 35739 (x1) from GSC loc. C-11868, Yukon Territory.

Figures 14, 15. Dorsal and anterior views (dorsal valve on top), GSC 30810 (x1) from GSC loc. 26406, Assistance Formation, Devon Island.

Figure 16. Ventral interior, GSC 30809 (x1) from same locality as figs. 14, 15.

Figure 17. Ventral valve, GSC 35734 (x1) from same locality as figs. 14, 15.

Figure 18. Posterior view, GSC 30811 (x2) from same locality as figs. 14, 15.

PLATE 8