JB. Geol. B. A.	Sonderband 12	S 5—99	Wien, Juli 1966

Lower Carboniferous and Upper Permian Brachiopods from Nepal

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With 16 plates

Contents

Abstract

Twenty Permian and eight Carboniferous brachiopod species are described from the Upper Paleozoic beds of Nepal. Permian species are known from eleven fossil localities, and compare closely with Upper Permian Himalayan faunas from the Productus Shales, Chitichun 1, Kuling Shale, and Zewan beds of Kashmir, as well as the Upper Productus Limestone of the Salt

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Range. The faunas are correlative with the Upper Permian *Cyclolobus* zone, generally presumed to come at the top of the Paleozoic succession, although possibly not as young as some Permian faunas of Japan and New Zealand. Two new genera are proposed, *Multispinula* with type species *Strophalosia maxwelli* WATERHOUSE (1964 c), considered to include many species previously referred to *Strophalosia*, and *Fusispirifer*, with type species *Spirifer nitiensis* DIENER (1897 b). Newly named species are *Orthotetes bisulcata*, *Anidanthus fusiformis*, *Costiferina alata*, and *Fusispirifer plicatus*, and various other Upper Permian species are revised from examination of type material from the Salt Range and Himalaya, notably species of '*Strophalosia*', *Neospirifer moosakhailensis*, *N. ravana*, *Spiriferella rajah* and *S. tibetana*. Lectotypes are designated for *Strophalosia indica* WAAGEN, *S. lamellosa linearis* REED, *S. tenuispina* WAAGEN, *S. nodosa* WAAGEN, *Productus opuntia* WAAGEN, *Ruthenia purdoni castrensis* REED, *Productus indicus* WAAGEN, *Productus lineatus* WAAGEN, *Spirifer moosakhailensis* DAVIDSON, *S. ravana* DIENER, *S. nitiensis* DIENER, *S. byroensis* GLAUERT, *S. tibetanus* DIENER, and *Athyris subexpansa* WAAGEN, these being species of particular relevance to the present study. Carboniferous brachiopods are known from three localities, and compare with species from the Syringothyris Limestone of Kashmir and Lipak beds of Kanaur and Spiti. They are probably Tournaisian. Newly named species and subspecies are *Linoproductus pollex*, *Fusella mucronata*, and *Syringothyris curzoni glaber*.

Zusammenfassung

Es werden zwanzig permische und acht karbone Brachiopodenarten aus dem Jungpaläozoikum der Tibet Zone von West Nepal beschrieben. Das Fossilmaterial wurde von Dr. G. FUCHS im Zuge der geologischen Aufnahme des unter dem Namen Dolpo bekannten Gebietes und im Dhaula Himal aufgesammelt. Diese Untersuchungen wurden im Rahmen der von der Österreichischen Himalaya-Gesellschaft durchgeführten „Österreichischen Dhaula-Himal-Expedition 1963" vorgenommen. Ein vorläufiger Bericht (G. FUCHS 1964) gibt einen Überblick über den geologischen Aufbau des Gebietes, 1967 soll eine ausführliche Darstellung der Geologie dieses Raumes erscheinen. Von elf Fossilpunkten sind permische Arten bekannt. Sie stehen anderen oberpermischen Faunen des Himalaya, wie denen aus den Productus Schiefern, von Chiticun 1, den Kuling Schiefern und den Zewan Schichten Kashmirs sowie aus dem Oberen Productus Kalk und der Salt Range sehr nahe. Die Faunen entsprechen der Cyclolobus Zone des Ober Perm, die allgemein als das jüngste Schichtglied der paläozoischen Abfolge betrachtet wird, obwohl möglicherweise gewisse permische Faunen Japans und Neuseelands noch jünger sind. Zwei neue Gattungen werden vorgeschlagen, *Multispinula* mit *Strophalosia maxwelli* WATERHOUSE (1964 c) als Typusart, sie enthält anscheinend viele Arten, die bisher zu *Strophalosia* gezählt wurden, und *Fusispirifer* mit *Spirifer nitiensis* DIENER (1897 b) als Typusspezies. Neue Arten sind *Orthotetes bisulcata*, *Anidanthus fusiformis*, *Costiferina alata* und *Fusispirifer plicatus*.

Verschiedene andere oberpermische Arten wurden bei der Durchsicht des aus der Salt Range und dem Himalaya stammenden Typusmaterials revidiert, nämlich „*Strophalosia*", *Neospirifer moosakhailensis*, *N. ravana*, *Spiriferella rajah* und *S. tibetana*. Lectotypen werden angegeben für *Strophalosia indica* WAAGEN, *S. lamellosa linearis* REED, *S. tenuispina* WAAGEN, *S. nodosa* WAAGEN, *Productus opuntia* WAAGEN, *Ruthenia purdoni castrensis* REED, *Productus indicus* WAAGEN, *Productus lineatus* WAAGEN, *Spirifer moosakhailensis* DAVIDSON, *S. ravana* DIENER, *S. nitiensis* DIENER, *S. byroensis* GLAUBERT, *S. tibetanus* DIENER und *Athyris subexpansa* WAAGEN, welche Arten für die vorliegende Arbeit von besonderer Bedeutung sind. Karbone Brachiopoden sind von drei Fossilpunkten bekannt, sie sind mit Arten aus dem Syringothyris Kalk von Kashmir und den Lipak Schichten von Kanaur und Spiti zu vergleichen. Ihr Alter ist wahrscheinlich Tournais. Neu bekannte Spezies und Subspezies sind *Linoproductus pollex*, *Fusella mucronata* und *Syringothyris curzoni glaber*.

Introduction

The brachiopods described in this report were collected from the Dolpo District of West Nepal by Dr. Gerhard R. FUCHS in 1963 *) (FUCHS, 1964). As shown in the list of localities (Table 3), three collections are of Carboniferous species, preserved as rather small and broken specimens in calcareous mudstone. The material responds very well to leaching in hydrochloric acid, although some specimens proved to be filled internally with calcite. On the whole they indicate a Lower Carboniferous age, perhaps a little older than the correlation high in the Lower Carboniferous suggested on the basis of the corals after a preliminary examination by FLÜGEL (1964).

The remainder of the brachiopods are Upper Permian, in conformity with the corals examined by FLÜGEL. As outlined in FUCHS (1964) and Table 3, they come from a variety of lithologies, ranging from quartzose sandstone at the base of the Permian above the Lower Carboniferous, through non-calcareous to highly calcareous mudstones and coarse-grained limestones at the top of the succession, immediately below the Triassic. None of the faunas are particularly rich in terms of species, but individuals of some Productoid and Spiriferoid species are unusually large. Like other material collected from the Himalaya, most specimens are preserved as natural or partially leached moulds which show internal and external detail well, in contrast to the richer faunas of the Salt Range of West Pakistan, and also from Chiticun 1, in which the specimens are preserved chiefly as shells with fine surface detail often lost, and internal detail hidden. Only some of Nepal material has the shell intact. The detail thus preserved enables an enlarged understanding of several important species. A warning must however be sounded on one aspect of the preservation of the Nepal material. Most specimens are moderately to considerably distorted, as well as broken, and for this reason, the variation in dimensions given for the specimens should be treated with caution.

*) G. FUCHS was a member of the Dhaula-Himal-Expedition 1963 which was organized by the Österreichische Himalaya-Gesellschaft.

Scope of the present work

Before being presented with the task of describing the Nepal material I spent four weeks at the Geological Survey of India, Calcutta, examining type Permian and Carboniferous specimens from the Salt Range, Himalayas, Yunnan and Chitral. Valuable information on many of the types to which the Nepal species are referred was gained in this way, and is incorporated in the present work, together with observations on types of related forms, particularly from Madagascar and Indonesia. First hand examination of the Salt Range types in particular proves to be indispensable as some of the figures in the major works by WAAGEN and REED are highly misleading. The reader should be warned that examination at Calcutta had to be very rapid, and that only the types were seen, rather than fully representative collections, which give unduly restricted concepts of the species involved. Unfortunately the Nepal material was not to hand while I was working at Calcutta, but I have been able to compare the Nepal material with specimens collected from various parts of Kashmir by Dr. FUCHS, and from the Salt Range collected by myself.

Acknowledgements

I am particularly grateful to Dr. G. FUCHS for kindly giving me the opportunity of describing the Upper Palaeozoic brachiopods from Nepal, and to Dr. R. W. WILLETT and C. A. FLEMING, Director and Chief Palaeontologist of the New Zealand Geological Survey, for granting permission to conduct the study. Acknowledgements are due to the Chief Palaeontologist, Mr. M. V. A. SASTRY and Palaeontologist Mr. S. C. SHAH, Geological Survey of India, for their help in enabling me to examine the various Upper Paleozoic brachiopod types at Calcutta, and to Mr. FATMI, Pakistan Geological Survey, for guiding me through sections of the Salt Range. Prof. L. P. G. KONING, Geologisch Institut, Universität of Amsterdam; Dr. J. H. UBAGHS, Mineralogisch geologisch Museum, Technische Hogeschool, Delft; Prof. G. H. R. von KOENIGSWALD, Mineralogisch-Geologisch Instituut, Rijks Universitet, Utrecht, and Dr. H. K. ERBEN, Geologisch-Paläontologisches Institut und Museum, Rhein Friedrich-Wilhelms-Universität, Bonn, kindly assisted me to examine type specimens and other Permian collections from Timor, and Prof. G. ASTRE, Museum d'Histoire Naturelle de Toulouse, to see the Upper Permian collection from Madagascar. Dr. FUCHS kindly sent microfilm of papers not available in New Zealand, and I also thank the typist, Mrs. M. BROWN, and photographer, Mr. S. N. BEATUS, for their help.

Permian

Genus *ORTHOTETES* FISCHER DE WALDHEIM (1850)

Type species: *Orthotetes radiata* FISCHER (1850).

Diagnosis: Both valves convex, or ventral valve resupinate, hinge wide, umbo usually undistorted, shell non-plicate. Ventral valve with small

spondylium supported by median septum, probably formed by the spondylial plates, dorsal valve with short, non-recurved crural plates, no median septum.

Discussion: Sarytcheva and Sokolskaja (1952) and Sokolskaja (1954) showed that the spondylium in species from the Moscow Basin is small and continues into the supporting median septum, whereas Campbell (1957) and Thomas (1958) provided evidence for an independent septum in Carboniferous and Permian forms in Australia, and therefore erected new genera. I do not have at my disposal sufficient material to exhaustively examine the structure in the Nepal specimens, but a polished section shows a median white line down the septum, as though the septum were composed of the plates, as is said to be the case for *Orthotetes*. This is not conclusive, but is taken provisionally as a guide.

Orthotetes bisulcatus n. sp.

Pl. 1, figs. 1, 4; Pl. 2, figs. 3, 4; Pl. 3, fig. 1

Material: More than 11 dorsal valves and three ventral valves from F 112, preserved as shells in a calcareous matrix.

Holotype: Specimen figured in pl. 1, fig. 1.

Diagnosis: Bisulcate *Orthotetes* with low ventral umbo little extended posteriorly, ventral valve undulose in longitudinal profile, most inflated close to umbo, dorsal valve convex, most inflated near mid-length, costellae of moderate strength.

Dimensions (in *mm.*):

Width	Length	Height	Length Septum	Cardinal Angle	Sulcal Angle	Costellae in 5 *mm.* at anterior margin
			Ventral valve			
?18	?13	?2		120°	40°	8
33	21	4.8		120°	38°	8
?39.5	22	4.8	8.2	130°		7
			Dorsal valve			
			Crural plates from hinge			
32	19	5	2.4			10
37	26	3.8	3.5	120°	27°	7
42	25	4	?3	115°	23°	9

Description:

External: Although somewhat variable in outline and profile, the specimens are consistently transverse, and little inflated, with obtuse cardinal extremities. The ventral valve has an inconspicuous umbo, with an angle of 160°, not raised above the rest of the valve or extended posteriorly, and no ears are differentiated. The interarea is too poorly exposed to be described. The maximum inflation lies near the posterior end of the shell, and the shell tends to become concave in front, and then convex again

near the anterior margin. A median flattening is developed in the largest specimen, and the other two ventral valves have a shallow wide-floored median sulcus. All of the dorsal valves have a similar sulcus, and are convex throughout their length, with the maximum height at mid-length or a little in front. The dorsal umbo is slightly more raised than that of the ventral valve. Costellae are narrow and high with rounded crests, sometimes slightly flexuous, and increasing regularly by intercalation. They are crossed by low growth-lines, about 4 and up to 10 per millimetre, arching posteriorly in the interspaces. Possibly 6 to even 12 pits occur per millimetre, but this is uncertain; in places the surface appears to be radially striated (24 per millimetre), but preservation is too poor to allow certainty.

Internal: Internal details are not well exposed. One specimen has a small spondylium between the teeth, supported by a median septum which extends for a third of the length of the shell. A polished surface across the septum in another specimen shows a dense median white line down the middle, possibly at the junction of the two plates that form the spondylium, and so suggestive of a spondylium duplex.

In the dorsal valve the crural plates diverge anteriorly at 115° to 135°, and are virtually straight in outline, with a concave anterior face. A narrow median process lies on the posterior face of the cardinal process, within a median depression, and a second wide depression lies each side, and a small plate lies against the hinge behind the crural plates. The anterior face of the cardinal process has a low median ridge. Adductor impressions are flabellate posteriorly, and subrounded in outline.

Resemblances: This species appears to be new. The Chitichun species described as *Orthotetes kraffti* DIENER (1897 a, pl. 3, figs. 6—7) is close in size and fine ornament, and has a sulcus in each valve, though it is more inflated, with the maximum inflation of the ventral valve placed further from the hinge and that of the dorsal valve closer to the hinge than in the new species. It is illustrated as having two short septa in the ventral valve, in accord with DIENER's understanding of the genus, and so is presumably not congeneric.

THOMAS (1958, p. 30) suggested that some of the Salt Range species described by WAAGEN and REED might belong to *Orthotetes*. Of these, the Upper Productus Limestone *Derbyia altestriata* WAAGEN (1883, pl. 52, fig. 2) is moderately close in shape and profile, but has coarser costellae. Another species from the Upper Productus Limestone, *Orthotetes semiplanus* WAAGEN (1883, pl. 55, figs. 1, 2) is somewhat similar in ornament, width of hinge and sulcation, but has a highly inflated ventral valve and almost flat dorsal valve. *Derbyia subsinuata* REED (1944, pl. 4, figs. 6, 7) from the Upper Productus Limestone has a comparable longitudinal profile and sulcus in both valves, but the ornament is finer, the hinge alate and the ventral umbo more extended posteriorly. Internal details are not well known.

From the Fenestella beds of Kashmir *Derbia dorsoplana* (DIENER, 1915, pl. 3, figs. 14, 15) seems to have a spondylium and costellae of similar density, but the costae are bifurcate, not intercalated, and the shell reaches a larger size and the dorsal valve was described by DIENER (1915, p. 34) as extremely flat.

Genus *NEOCHONETES* Muir-Wood (1962)

Type species: *Chonetes dominus* R. H. King (1938).

Diagnosis: Concave-convex capillate Chonetoids with shallow ventral sulcus and low dorsal fold, short ventral and long dorsal septum.

? *Neochonetes* sp. or spp. indet.

Pl. 1, fig. 6

Material: An internal mould of a valve, possibly ventral, with muscle scars and hinge obscured from F 58, and a worn external mould of a dorsal valve from F 108.

Dimensions (in *mm.*):

	Width	Length	Height
F 58	28	14	2.2
F 108	30	16	4

Description: Preservation is so poor that even the generic position is obscure. The possible ventral valve has pustular radial ridges, 2 per millimetre at the anterior margin and 3 laterally, and a wide shallow sulcus, but is otherwise not known, even the outline being obscure. The dorsal valve has a very low median fold over the anterior half of its length, and the maximum width lies at mid-length on one side, and near the anterior third of the shell length on the other. Along the hinge is a flat interarea inclined ventro-posteriorly at 30° from the commissure, and one or two long cardinal spines of the ventral valve are preserved in the matrix. Apart from a few concentric growth-lines the surface of the mould appears to be smooth, but there is no certainty that capillae have not been worn from the surface.

Resemblances: As the ornament is not known, the generic position cannot be determined. In their subrectangular transverse outline and wide shallow sulcus and wide anterior low fold the specimens recall *Neochonetes wageri* (Muir-Wood, 1941, p. 12, pl. 1, figs. 8, 9) from the Lachi Series of Sikkim. Unlike that of the Nepal dorsal valve the hinge of *N. wageri* lies at the maximum width of the shell, and the capillae would appear to be fine, Muir-Wood reporting 40 in 10 *mm.* at the anterior margin. For all that is known the two may not even be congeneric, though the shape does not agree with the outline of any *Lissochonetes* known from the region.

From Chitral (Horizon D) *Chonetes variolata baroghilensis* Reed (1925, p. 40, pl. 3, figs. 1—3) is rather similar in shape and sulcus, apart from a long high specimen figured in Reed (1925, pl. 3, fig. 4).

Genus *MULTISPINULA* n. gen.

Type species: *Strophalosia maxwelli* Waterhouse (1964 c).

Diagnosis: Strophalosiacea with umbonal cicatrix, interareas, inconspicuous growth-lamellae, sulcus and fold present or absent, anterior plicae rare, spines with long or short bases, erect and semi-recumbent on

ventral valve, fine and erect on dorsal valve. Ventral valve with teeth, dental callosities, oval adductor platform and diductor impressions. Dorsal valve with cardinal process, socket ridges, median septum, divided adductor platform.

Discussion: This genus is erected for New Zealand, Australian, and Asian species previously referred to *Strophalosia* KING (1844). Only two specimens are known of *Strophalosia gerardi* KING, the type species of *Strophalosia* by ruling of the International Commission for Zoological Nomenclature (Opin. int. Comm. zool. Nomen. 625, 1962) in response to a request from MUIR-WOOD (1960). As far as can be seen from examination both specimens lack spines from the dorsal valve, in confirmation of the opinion expressed by PRENDERGAST (1943), REED (1944), and KING (1938), and recently checked and confirmed by Dr. H. BRUNTON (British Museum) Natural History, London, and in spite of assertions to the contrary by MUIR-WOOD (1950) and MUIR-WOOD and COOPER (1960). Dorsal spines could have been rubbed from the types of *gerardi*, but it seems more likely that they were never present, especially as spines remain on the ventral valve. The type species of the new genus is selected because it is well preserved, with numerous specimens available from the type locality. Within the group of species referred to *Multispinula* are two major plexi, a southerly group extending north with short or no spine bases within the shell of the ventral valve, and another group with elongated spine bases.

Multispinula indica (WAAGEN, 1884)

Pl. 1, figs. 2, 3; Pl. 4, fig. 1; Pl. 8, fig. 3

1884 *Strophalosia indica* WAAGEN, p. 648, pl. 65, figs. 1—4.
1944 *S. lamellosa linearis* REED, p. 103, pl 6, figs. 1, 1a, 2.

Material: Internal moulds of three ventral and a dorsal valve, with fragments of the external moulds, from F 112.

Lectotype: (Here designated). Specimen figured by WAAGEN (1884, pl. 65, fig. 1, and text fig. 19). Kept at Geological Survey of India, Calcutta.

Diagnosis: Small *Multispinula* with large umbonal cicatrice and numerous moderately strong ventral spines, of which some are adpressed and others erect, anterior margin irregularly plicate. Dorsal spines fine.

Dimensions (in *mm.*):

Width	Length	Height	Hinge Length	Adductor Width	Adductor Length	Diductor Width	Diductor Length
9	10.5	3.5	6	2.4	3	1.8	2.5
9.5	11.6	1.6	?5.3	?1.8	?1.6	2.0	1.9

Description:

External: The specimens are small and subrounded in outline, the dimensions being compromised by lateral crushing which has exaggerated the length and height. A large umbonal cicatrice is developed on two of the ventral valves, but is not so clear on the third rather obscure specimen. The hinge is about two thirds of the width of the shell in one specimen, with small ears, a cardinal extremity measuring 100°, and a flat cardinal

interarea of moderate height lying almost in the plane of the commissure. In another specimen the hinge is a little shorter, and the cardinal extremities slightly acute. The maximum width of the shell lies at mid-length, and there is no ventral sulcus, but one or two short plicae are developed at the anterior margin. Little is known of the exterior of the dorsal valve, but signs of spines can be seen in the adjoining matrix. Spines are well developed and numerous on the ventral valve with a diameter of 0.4 to 0.5 *mm.*, and spaced somewhat irregularly at intervals of up to 1.2 *mm*, along rows about 1 *mm.* apart. Many are erect, but others are sessile for 4 *mm.*, and lie adpressed to the surface in a trough, as is also suggested by corrugations on the surface of the best-preserved internal mould. About 10 to 12 concentric growth lines and 8 radial striae per millimetre are present.

Internal: The ventral adductor platform is posteriorly placed, slightly raised, smooth, and subdivided by a low ridge, which is strongest posteriorly, and fades in front, failing to reach the anterior margin. The diductors are lightly impressed, overlap the adductors for the anterior third of their length, and are not noticeably scarred by longitudinal striae, but carry faint striae parallel to the posterior lateral margin. The remainder of the surface of the valve is marked by small pustules, about 2 occurring per millimetre, and by the tubular bases of spines. The teeth are small and close-set, without dental callosities (see WATERHOUSE, 1964 c).

The fragmentary dorsal valve has lost the shaft of the cardinal process but shows the dental sockets each side of high short ridges which diverge from the base of the process at about 100°. The median septum is highest just in front of the process, and beyond the posterior third of the shell length is very narrow and low, extending a little beyond mid-length. It divides two feebly defined subtriangular raised adductor scars. A few low pustules lie in front.

Resemblances: Individuals of the Strophalosid group of species and genera are highly variable and it is generally advisable to allow for considerable intraspecific variation, especially in regard to the proportions of width, length and height, and to a lesser degree spinosity. On the other hand, internal features, within limits, have been found to be constant in species (WATERHOUSE, 1964 c). Unfortunately such details are rarely available for Salt Range and Himalayan species. But in most respects the Nepal specimens are similar in shape, cardinal area, lack of a sulcus, short hinge, large cicatrice and presence of dorsal spines to *Strophalosia indica* WAAGEN of the Upper Productus Limestone. Examination of the types at Calcutta confirmed WAAGEN's observation that some of the spines are closely adpressed to the shell, so that the shell is raised each side. Though the recumbent spines do not lie in a set pattern, they tend to occur in rows, but probably only by accident. These recumbent spines are not so evident in the Nepal specimens, probably because they are small, and immature. Specimens of *S. indica* which I collected from the Upper Productus Limestone at Chhiddru also have comparatively short bases at early stages of growth.

About 6 concentric growth-lines were counted per millimetre on *S. indica* but there are many finer lines as well. Traces of radial lirae were seen though their presence was denied by WAAGEN. The elongated specimens from the Anthracolithic of the Shan States compared to *S. indica* by DIENER (1911,

pl. 5, figs. 19, 20) have the spines set on undulating costae, or long bases —possibly the former, and arranged more or less in quincunx. Anteriorly in F 10329 (fig. 19) the pattern changes to one of fine recumbent spines 1 *mm.* apart in concentric rows varying up to 2 *mm.* apart, with a few intervening strong erect spines. On the dorsal valve the spines are arranged in quincunx arising from sessile bases, between regular concentric ridges. F 10330 (fig. 20) has posterior spines in quincunx on long low wide spine bases (rather than costae), with shorter bases over the mid-length, and probably similar to the other anteriorly, though the scattered erect spines are more prominent, and the fine rows obscure, possibly because the shell is smaller and so not at a comparable stage of growth.

The Basleo specimens assigned to *S. indica* by BROILI (1916, pl. 118, figs. 9, 10) are similar in shape, but seem to have slightly finer spines, a shallow sulcus and an inconspicuous umbonal cicatrice, and so are not considered to be conspecific. *S. lamellosa linearis* REED (1944, pl. 6, figs. 1, 1 a, 2) from the Upper and ? Middle Productus Limestones appears to have long recumbent and a few strong erect spines on the ventral valve, and no costae, much as in *indica*, though the spines are not quite as long, nor the recumbents as thick. Also the cicatrice scar is a little smaller. A lectotype F 16879 (pl. 6, figs. 1, 1 a) is designated herein. On an unfigured specimen the dorsal valve is concave with either very high pustules, or more likely, erect spines. The specimens are likely to be conspecific with *indica*.

From the Middle Productus Limestone, *S. rarispina* (WAAGEN, 1884, pl. 65, figs. 6—9) also has large erect and recumbent spines on the ventral valve, with spines especially prominent on the interior shell of F 3658 (fig. 6). On the whole there are fewer recumbents and more erect spines than in *indica*, and the cicatrice is slightly smaller. Its dorsal valve is unknown externally, and in the interior of F 3658 (fig. 8) the septum extends to mid-length, without a posterior hump.

The Lower Productus Limestone species *S. tenuispina* WAAGEN (1884, p. 654, pl. 64, figs. 2—7) has subdued costae and recumbent or erect spines in F 3645 (fig. 2) here designated as lectotype, and possibly in F 3649 (fig. 6), the ribs starting at about the posterior third or half of the shell length, and seemingly not caused just by pressing up of the mantle by recumbent spines. They are more within the shell than on the surface. But the ribs are lower than in *S. plicosa* (WAAGEN), with more recumbent spines and fewer erect ones, and all of them finer. Large erect spines occur on the ears in F 3650 (fig. 7), up to 0.8 *mm.* in diameter compared with 0.4 *mm.* for the body spines. About 6 to 7 radials occur per millimetre in this specimen and 6 in F 3645, as well as 6 concentrics per millimetre. Although the dorsal valve of F 3649 is shown as smooth in the figure, it is in fact covered by matrix, and a few erect spines can be seen at the edge of the shell, and the same is true for F 3650 (fig. 7). REED (1944) and MUIR-WOOD and COOPER (1960) erroneously considered *tenuispina* to lack dorsal spines. Figures of the dorsal interiors are rather misleading. The area is flat and lies in the plane of the commissure in F 3650.

The Zewan specimen compared to *tenuispina* by DIENER (1899, pl. 1, fig. 17) has a small adductor platform, a plane area, no external ornament, and no sulcus. Large hollows indicate spine bases.

Two Salt Range species stand apart from this group in lacking recumbent spines. These are *S. nodosa* WAAGEN (1884, pl. 64, figs. 8, 9) from the Lower Productus Limestone, and *S. densispinosa* REED (1944, pl. 6, figs. 7, 8) from the Lower Productus Limestone. The former, for which F 3652 (fig. 9) is designated herein as lectotype, has traces of radial striae, and fine concentric lamellae, about 20 per millimetre, though the density varies considerably. Spines occur up to 0.8 to 0.9 *mm.* in diameter, though others are only 0.3 *mm.* wide. They are not very regularly disposed and WAAGEN's figures present their position inaccurately. The pattern is not very different from that of *tenuispina*, but the low "costae" formed by spine bases and upwelling of the mantle by pressure from recumbent spines seem to be missing. Probable but not definite dorsal spines occur on F 3651. The probably conspecific specimen described as *nodosa elongata* REED (1944, pl. 6, fig. 5), has several dorsal spines over the anterior half of the shell.

S. densispinosa has spines that are often recumbent and dense, but lack long bases, or sign of costae. A sulcus is present as in the lectotype of *nodosa* and the spines are as fine as in the paratype of *nodosa*, so that the two could prove synonymous, for they are of much the same shape.

Heteralosia sublamellata REED (1944, pl. 6, figs. 6, 6 a; pl. 7, figs. 8, 8 a, 9, 9 a, 9 b) from the Lower Productus Limestone has spines evenly spaced in quincunx on the ventral valve, but unlike those of *nodosa* they are of even diameter, and emerge at a constant angle of 30° from the surface of the shell. In other respects the species is close to *nodosa*. The ventral area is low and lies in the plane of the valve. Although considered by REED to lack dorsal spines, the dorsal valve is covered in matrix except for a small posterior part, so that presence or absence is difficult to establish.

S. blanfordi REED (1944, pl. 6, figs. 3, 3 a) from the Upper Productus Limestone has very long spine bases with a ramp from which the spines emerge. The dorsal valve has dimples or pustules, but it is not certain whether it is spinose. No interarea can be seen, and a deep posterior median cleft in the cardinal process suggests that the form is not of the Strophalosiacea.

Genus *KROTOVIA* FREDERIKS (1928)

Type species: *Productus spinulosus* J. SOWERBY (1814).

Diagnosis: Highly concavo-convex shells with thin visceral disc and large ears, ventral valve ornamented by round or slightly elongated spinose tubercles, and fine growth-lines, spines fine and growth-lines more prominent on dorsal valve.

Krotovia opuntia (WAAGEN, 1884)

Pl. 2, figs. 1, 5

1884 *Productus opuntia* WAAGEN, p. 707, pl. 79, figs. 1, 2.
? 1916 *P. opuntia* BROILI, p. 17, pl. 117, figs. 9, 10.

Material: A specimen with valves conjoined from F 112, dorsal valve a little decorticated, ventral valve with external mould.

Lectotype (Here designated): Specimen figured by WAAGEN (1884, pl. 79, fig. 1 a—k). Kept at Geological Survey of India, Calcutta.

Diagnosis: Medium-sized for genus, with wide hinge, moderately high shoulders, little extended ventral umbo, and comparatively well spaced large spines. Less transverse than WAAGEN's types.

Dimensions (in *mm.*):

Width	Length	Length Dorsal	Height
15.5	22	18	7

Description: The specimen is small and ovally elongated in outline, with a slightly incurved ventral umbo, of which the umbonal angle measures about 95°, and a very inconspicuous dorsal umbo. The hinge is wide, with large ears, set ventrally from the commissure, and seemingly obtuse cardinal extremities of which the angle measures about 100°, though they are possibly broken. The remainder of the shell outline is oval, with the maximum width placed between mid-length and the anterior third. The visceral disc is very thin, and the trail if present continues in the curvature of the visceral disc, for there is no angulation or geniculation. There is no ventral sulcus or dorsal fold, but a faint median flattening or reduction of curvature appears in cross-profile on the ventral valve only, possibly due to slight distortion.

On the ventral valve ornament consists of erect spines or tubercles arranged in regular rows and alternating in quincunx, the rows being about 1.8 *mm.* apart at 5 *mm.* from the umbo, with 4 to 5 spines in 5 *mm.* along a row. The spacing between rows gradually increases to 2.5 *mm.*, but is reduced to 1.5 *mm.* for the peripheral two rows, where the spines have the same spacing as near the umbo. The diameter of the spines or tubercles increases anteriorly from roughly 0.4 *mm.* near the umbo to 0.6 *mm.* in front. The remainder of the surface of the valve is marked by wavy concentric striae and possible radial striae, but growth-lines cannot be clearly discerned. On the dorsal valve concentric growth lamellae are more evident, 0.5 to 1 *mm.* apart, and interrupted by the hollow cores of spines which are a little denser than on the ventral valve, 6 occurring in 5 *mm.* along rows 1 *mm.* apart in the middle of the shell at mid-length. Some of the spine bases seem to form low tubercles but this could be the result of weathering. Fine spines are scattered over the dorsal ears, between low tubercles which probably oppose the spines of the ventral ears. Neither valve appears to have any special row along the inner ears or hinge.

The shell is about 0.4 *mm.* thick at the broken ventral umbo. Nothing is visible of the interior except for the inner ear of the ventral valve, which is marked by fine sharp pustules, and the broken tip of the umbo, which as would be expected shows no median septum.

Resemblances: The specimen is moderately close to *Productus opuntia* WAAGEN (1884, p. 707, pl. 79, figs. 1, 2) from the Upper Productus Limestone in the spacing of spines, and oval shape umbo and hinge, but is less transverse, and smaller. Basleo specimens referred to *P. opuntia* by BROILI (1916, p. 17, pl. 117, figs. 9, 10) are slightly narrower and smaller, but otherwise similar in shape. The specimen recorded from the North

Caucasus by LIHAREV (1936, pl. 7, fig. 14) is certainly close in shape, but it is not completely clear from the figures whether it belongs to *Krotovia* or not. Djebel Tebaga specimens sketched by H. and G. TERMIER (1957) could be allied, though they were referred to *Waagenoconcha*, suggesting they belong to a different genus.

K. curvirostris (SCHELLWIEN, 1892) as figured by MANSUY (1913 a, pl. 2, figs. 9 a—c) has a more extended ventral umbo, fewer spines and raised short costae or elevations.

K. pustulata (KEYSERLING, 1854) as figured by ČERNYŠEV (1902), MANSUY (1913 a), GRABAU (1936) and other authors has much finer spines, and *K. translata* REED (1931 b, pl. 1, figs. 6—8) from the Permian of Afghanistan is more transverse with a more extended umbo and slightly elongated spine bases. Various species from Western Australia have finer close-set spines. These include *K. senticosa* (HOSKING, 1933, pl. 3, figs. 2, 3) referred to *Krotovia* by PRENDERGAST (1943, p. 30) and figured by COLEMAN (1957, pl. 7, figs. 11—15), *K. micracantha* (HOSKING, 1933, pl. 4, figs. 4 a, b), referred to *Krotovia* by PRENDERGAST (1934, p. 28) and refigured by COLEMAN (1957, pl. 7, figs. 16—18; pl. 9, figs. 20, 21), and *Krotovia* referred (erroneously) to *K. spinulosa* (SOWERBY) by PRENDERGAST (1943, pl. 4, figs. 11—13) and COLEMAN (1957, pl. 7, figs. 19—24).

K. wallaciana (DERBY, 1874, pl. 3, figs. 46—48; pl. 6, fig. 5) from Brazil is moderately similar in shape and possibly ornament, but is not well known. The form named by DIENER (1911, p. 25, pl. 4, figs. 3—5) from the Shan States is elongated and inflated with scattered fine spines and suggestions of short radial costae, so that it is probably not congeneric.

Genus *MARGINIFERA* WAAGEN (1884)

Type species: *Marginifera typica* WAAGEN (1884).

Diagnosis: Concavo-convex shells with large ears and poorly to well defined costae, low wrinkles, scattered spines on ventral valve, especially on flanks, no dorsal spines. Ventral valve with smooth adductor platform, oval diductors, low marginal ridge, dorsal valve with large cardinal process, wide posterior septum, dorsal adductors in two smooth pairs, marginal ridge around visceral disc crenulate.

Marginifera sp.

Pl. 3, figs. 3—5

Material: A possible dorsal and a ventral valve and a specimen with valves conjoined from F 108.

Diagnosis: Characterised by coarse branching costae, few spines, small size, thick shell and deep narrow to broad sulcus.

Dimensions (in *mm.*):

Valve	Width	Length	Height	Umbonal Angle	Sinal Angle	Cardinal Angle
Dorsal	25.5	18.5	12	?130°	35°	130°
Ventral	28	19.5	12.5	120°	42°	?140°
Ventral	30	22	13	125°	35°	?145°

Description:

External: The shells are small, transverse and well inflated, with a low broad umbo, extended little beyond the hinge in the dorsal valve and more massive and raised in the other shells. The hinge is wide, and the maximum width lies just in front, with obtuse cardinal margins and ill-defined long ears, largely destroyed. A broad sulcus and fold arise a little in front of the umbo and deepen towards the anterior margin, with an angle of 27° in the dorsal valve, and nearly 40° in the ventral. The visceral disc is rounded and the trail rounds smoothly from the ventral disc, and at an angle in the dorsal valve. Dorsal ornament consists of 36 costae at the anterior margin, decreasing in width anteriorly, with rounded crests, 4 occurring in 5 *mm.* at the anterior margin, compared with 6 in 5 *mm.* near mid-length. Interspaces become relatively wider anteriorly. Costae branch anteriorly each side of the sulcus. A few short spine bases lie over the crests, no wider than the costae, and the costae are crossed by about 4 growth-lines per millimetre near the anterior lateral margin, arching posteriorly over the costae. Low concentric growth wrinkles are present posteriorly. The two decorticated specimens show nothing of the external ornament, and costae are not visible internally.

Internal: The decorticated ventral valve shows traces of a smooth adductor platform, divided by a median ridge, and adjoined laterally by subrounded diductor impressions. The other specimen, with valves conjoined, was sacrified in acid to examine the internal features, and showed similar muscle scars, that later became somewhat obliterated with further leaching. The diductors extended a little in front of the adductor platform, and were longitudinally striated. Heavy thickening lay each side of the umbonal cavity, almost like Strophalosiid teeth.

The cardinal process of this specimen displays a huge myophore head and broad shaft lying in the plane of the commissure, passing into the broad posterior part of a median septum. It seems to be succeeded by a median groove that extends from behind the adductor platform to the marginal ridge of the visceral disc, but is obscure between the adductors, where leaching is incomplete. The adductors are raised and probably subrounded in outline. The remainder of the floor of the valve is lightly dimpled, and striated, and crural ridges are not obvious. Short supporting ridges diverge from the cardinal process, just in front of the fluted marginal ridge which encircles the disc.

Resemblances: The Nepal specimens compare moderately well with *Marginifera himalayensis* Diener, specimens of which were collected for me by Dr. G. Fuchs from beds just above the *Protoretepora ampla* horizon at North Barus (K 16), Kashmir. The dorsal valve with its ornament visible has slightly stronger costae anteriorly — and a similar but longer trail than usual. The ventral valves are close in longitudinal profile, but have a wider sulcus than in the Kashmir specimens. All of Diener's figures seem to differ in these respects (1899, pl. 2, figs. 1—7; pl. 6, figs. 1—2; 1903, pl. 5, figs. 5—6, 27; 1915, pl. 8, fig. 9) so that Nepal specimens may not be conspecific. The Lachi specimens figured by Muir-Wood (1941, pl. 1, figs. 1—3) also seem to have the narrow ventral sulcus, and perhaps fine costae anterior-

ly, though the figures are poor. The specimen from the Anthracolithic of the Karakorum Mountains described by MERLA (1934, pl. 26, figs. 12, 13) is small with rather fine ornament.

Marginifera typica WAAGEN (1884, pl. 68, fig. 1; pl. 76, figs. 4—7) is possibly more closely allied for its costae persist well to the anterior margin. Specimens figured by WAAGEN show a high shell somewhat as in the better preserved ventral valve from Nepal, but with more enrolled ventral umbones. However a specimen collected by me from the top Middle Productus Limestone of the Zaluch Nala in the Salt Range has a less enrolled umbo. WAAGEN's figured specimens and this one have a narrow sulcus and a distinctive spine pattern. Unfortunately spines are not known for the Nepal specimens. WAAGEN'S specimens possibly have the trail broken short. DIENER (1897 a, pl. 4, figs. 11—13) figured Chitichun specimens with a rather shallow sulcus and fine costae, like specimens figured by MUIR-WOOD and COOPER (1960, pl. 60, figs. 5—8) and DAVIDSON (1862, pl. 1, fig. 14). The Basleo specimens so identified by BROILI (1916, pl. 117, figs. 6, 7) have rather low costae, and a moderately wide sulcus arising in front of the umbo, but the Bitauni specimen (fig. 8) lacks costae and is unlikely to be conspecific. OZAKI (1931, pl. 12, fig. 21) figured a small specimen with coarse costae, unlikely to be conspecific, but an Upper Permian Kueichow specimen named *M. typica elongata* by HUANG (1932, pl. 1, fig. 14) has sturdy costae like the Nepal specimen, though it is a narrower shell. Karakorum shells so-named by MERLA (1934, pl. 25, figs. 16—23) are also elongated with sturdy costae, but practically lack a sulcus, like the Maping form *M. typica tenuistriata* GRABAU (1936, pl. 14, figs. 6—8), which is characterised by fine costae.

From the so-called Upper Carboniferous of Chitral REED (1925, p. 10€, pl. 5, fig. 4) described a new species, *Marginifera praelectus*, which shows some approach to the ornamented Nepal specimen. The two are of similar shape, with more or less similar ears and sulcus and radial costae, but concentric wrinkles are better defined on the Chitral specimen.

From the Productus Limestones REED (1944) erected a number of species which would appear to require re-assessment; none are any closer to the Nepal specimens than *typica* or *himalayensis*. It seems likely that the Nepal specimens belong to either of these two species, and that of the two *typica* is slightly closer, but the absence of information on spine pattern hinders further identification.

Genus *ANIDANTHUS* WHITEHOUSE (1928)

Type species: *Linoproductus springsurensis* BOOKER (1932).

Diagnosis: Characterised by strongly developed concentric growth lamellae on the dorsal valve, crossing the usual ornament of radial costellae seen also on the ventral valve. Spines rare, along the hinge and scattered over ventral disc. Oval smooth adductor platform in ventral valve.

Discussion: WHITEHOUSE (1928, p. 282) proposed the name *Anidanthus* for specimens figured by ETHERIDGE (1892, pl. 12, fig. "16"—really 17; pl. 44, fig. 13) from the Burnett district and Gympie beds of Queensland. He gave no specific name, and no diagnosis of the genus or species. BOOKER (1932) claimed that the two represented different forms, and referred the

Gympie specimen to *Linoproductus springsurensis* BOOKER. The latter was briefly described by ETHERIDGE (1892, p. 257), the former unmentioned in the descriptions, unless it illustrates a description of *Productus semireticulatus* on p. 255.

HILL (1950, p. 9) however was satisfied that the two specimens were conspecific with *springsurensis*, though this seems hard to credit if the specimen in pl. 12, fig. 17 is really a ventral valve as claimed by ETHERIDGE. HILL stated that *Anidanthus* stood in jeopardy because of WHITEHOUSE's failure to define the genus or name the species, but asserted that the genus appeared valid as WHITEHOUSE used binary though not binomial nomenclature. To guard against loss of the name she also republished the name under her own authorship, though this step itself would appear to require 'validation' from the ICZN., as it makes use of a name already published.

A confusing sentence in MUIR-WOOD and COOPER (1960, p. 299) might be taken to mean that WHITEHOUSE had indicated that the specimen in ETHERIDGE (1892, pl. 44, fig. 13) is type species. This is not true. Neither of the two had been designated in particular as type, so that the conflict between BOOKER and HILL as to whether one or two species are represented has a bearing on the case. MUIR-WOOD and COOPER referred a number of species to *Anidanthus*, but warned that this was only a tentative and possibly temporary expedient. HILL (1950) stated that she had submitted the question of the validity of *Anidanthus* WHITEHOUSE to the International Commission on Zoological Nomenclature, but 15 years later I have yet to see a ruling, perhaps because the appeal never reached the Committee. In short WHITEHOUSE did not name the species, did not indicate a type specimen, or indicate the means by which the genus should be distinguished. The first of these points, the one that has worried MUIR-WOOD and COOPER, and HILL, is the failure to use binomial nomenclature. Such a lapse seems to be permitted for generic names published before 1931. Although making no description or diagnosis, WHITEHOUSE indicated specimens typical of his genus which had been previously described, and one of these at least was subsequently placed in a well-defined species, which may therefore be taken as type species, following normal procedure with *genus caelebs* (Dr. C. A. FLEMING, pers. comm.).

A second problem relating to *Anidanthus* is the question of its identity or distinction from *Pseudomarginifera* STEPANOV (1934), proposed for *Productus ussuricus* FREDERIKS (1924 a). MUIR-WOOD and COOPER preferred to recognise both genera, whilst emphasizing that *P. ussuricus* is poorly known, and stated that HILL considered the two to be congeneric.

In SARYČEVA (1960, pl. 38, figs. 3, 4) the ventral valve of *P. ussuricus* seems to have definite low concentric laminae or angular wrinkles over the posterior part of the visceral disc, unlike that of the type or other species referred to *Anidanthus*, so that though not mentioned by SARYČEVA, HILL, or MUIR-WOOD and COOPER, this might provide a difference between the two forms.

Family position: BOOKER (1932) and MUIR-WOOD and COOPER (1960) considered *Anidanthus* to be closely related to *Linoproductus*, *Cancrinella* and allies, but without having made a close study of the problem, I would suggest that *Anidanthus* is more likely to belong to the Margini-

feridae. It has similar ears and ornament, identical non-dendritric ventral adductors (in contrast to true members of the Linoproductidae), non-dendritic dorsal adductors, and traces at least of a marginal ridge (HILL, 1950). The nature of the cardinal process and other details are yet to be investigated.

Anidanthus fusiformis n. sp.

Pl. 4, figs. 1, 4, 5; Pl. 8, fig. 3

1897a *Productus cora* DIENER, p. 16, pl. 4, figs. 1 a—c.
1899 *Productus cora* DIENER, p. 22, pl. 1, figs. 12 a—c.
1899 *Strophomena analoga* DIENER, p. 51, pl. 2, fig. 17.
1915 *Productus waagenianus* not GIRTY, DIENER, p. 71, pl. 6, figs. 18—19; pl. 7, fig. 6.

Material: A fragment of external ornament from F 58, two exteriors of ventral valves from F 108, an exterior and other fragments of ventral valves, and a natural external mould of a dorsal and part of the ventral valve from F 112.

Holotype: Specimen figured in pl. 4, fig. 1, F 112.

Diagnosis: Transverse shells with ventral umbo not strongly incurved, alate at late stage of growth, anterior margin of ventral valve protruding moderately into concavity at margin of dorsal valve, costellae of moderate strength.

Dimensions in *mm.*):

Collection Number	Width	Length	Height	Cardinal Angle	Costellae in 5 *mm.* Posterior	Anterior
			Ventral valve			
108	23.5	15	7	110°	11	7
108	29	16.5	9			6
112	21.5	17	8.5		11	7
112	19.5	10.5	5.5	130°		7

Description:

External: The shells are small with a highly convex ventral valve and gently to moderately concave dorsal valve, so that the visceral disc is inflated. The ventral umbo is low and the posterior walls diverge anteriorly at 105° to 110°, whereas the dorsal umbonal angle measures 130° and 140° in two specimens. In outline the shells are rather variable. The position of maximum width seems to lie in front of the hinge on two somewhat obscure ventral valves, but appears to be placed at the hinge on another ventral valve, and growth-lines on the dorsal valve show that it became alate after reaching a width of over 11 *mm.* The trail is not geniculate, and is very thin, and flares out well beyond the disc, but is no longer intact, so that the dimensions given are somewhat imperfect. There is no sulcus or fold, although the ventral valve from F 112 is slightly flattened medianly and the dorsal margin is embayed medianly to receive a ventral tongue. On the ventral valve ornament consists of low flexuous costellae of the same size as the interspaces, increasing by intercalation, and crossed by low growth lines, about 5 occurring per millimetre. A few small erect spines seem to arise from the crests on some specimens, whereas others show no trace of spines, but preservation is too poor to determine the spinose pattern accurately. On the dorsal valve the costellae are crossed by laminar growth-

lamellae at intervals of 1 millimetre or less. A few narrow holes in the matrix suggest that a few spines may have been present, unless they represent pieces of calcite that had rested against the shell.

Internal details are not known.

Resemblances: These specimens are probably identical with specimens assigned to *Productus waagenianus* GIRTY by DIENER. One of the specimens from F 108 agrees very closely in the shape of the umbonal region with the ventral valve figured by DIENER (1915, pl. 6, fig. 18 a), the one noticeable difference being possibly in the finer costellae of DIENER's specimens, there being 10 in 5 *mm.* in his figures, if these are reliable. One of DIENER's dorsal valves (1915, pl. 6, fig. 19) seems to lack the median recession, but another (1897 a, pl. 2, fig. 17 a) has a wide shallow anterior embayment of the commissure.

Internal details of DIENER's specimens are not available for comparison, nor details of spinosity well known. One of the Chitral specimens figured by REED (1925, pl. 4, fig. 3) as *Productus cora aagardi* TOULA is moderately close in shape and ornament, though the remainder are oval in outline and less inflated with slightly more pronounced ears and a shallow anterior sulcus. In 1944 (p. 57) REED referred these specimens to the well-rounded "*Linoproductus*" *aagardi implicata* REED from the Middle Productus Limestone. He also suggested that the Chiticun *P. cora* of DIENER (1897 a, pl. 4, fig. 1) was conspecific; this has apparently coarse costellae (6 in 5 *mm.*) comparable with those of the Nepal specimens, but is a little more rounded in outline.

P. waagenianus GIRTY (1909, p. 253, pl. 12, figs. 6, 7) from the Capitan beds of Texas has 14 costellae in 5 *mm.* according to GIRTY, and a slightly more prominent incurved ventral umbo, and more extended ventral margin medianly. A Word specimen described by KING (1931, p. 77, pl. 17, fig. 10) has 7 to 14 costellae in 5 *mm.*, and 10 growth-lines per millimetre, with a very wider hinge and more rounded outline. Remaining specimens described by KING have large ears and were referred to *Megousia* by MUIR-WOOD and COOPER (1960). *P. eucharis* GIRTY (1910, pl. 2, figs. 3, 4) from the Phosphatia beds of Idaho also has finer ornament and a long hinge, and well rounded anterior margin, though one of the specimens figured in 1927 (pl. 28, fig. 23) is much closer in shape.

Of the Bitauni specimens referred to *waagenianus* by RENZ (1940), the specimens figured by BROILI (1916, pl. 116, figs. 1—3) have a more globular appearance and bifurcating coarse costellae. The specimens figured in pl. 115, figs. 14, 15 are moderately globular, and what seems to be the dorsal valve in fig. 15 does not appear to have concentric lamellae.

Lower Upper Permian specimens described from Anhui Province, China, as *Anidanthus sinosus* (HUANG) by ZHANG YAN and CHING TU-KAN (1961, pl. 3, figs. 1—5) are very close in shape, but somewhat smaller with low lateral wrinkles on the ventral valve. The original specimens described by HUANG (1932, p. 43, pl. 2, figs. 15, 16) have well defined lateral concentric rugae on one ventral valve, and rugae cross the anterior venter on the other ventral valve, suggesting a relationship to *Pseudomarginifera* STEPANOV.

Of Taimyr species figured by UTRITSKY and ČERNJAK (1963, pl. 11, figs.2 to 10), *A. diksoni* (EINOR) has finer ornament and *A. rugosus* (LIHAREV) coarser ornament. Both forms tend to be less transverse than the new species.

WAAGENOCONCHA Chao (1927)

Type species: *Productus humboldti* d'Orbigny (1842).

Diagnosis: Echinoconchidae distinguished by ornament of fine spines arising in quincunx over both valves, sometimes from short ridges, often decreasing in diameter anteriorly.

Waagenoconcha purdoni (Davidson 1862)

Pl. 4, figs. 2, 3; Pl. 5, figs. 2, 3

1862 *Productus purdoni* Davidson, p. 31, pl. 2, fig. 5.
1884 *P. purdoni* Waagen, p. 705, pl. 73, figs. ? 1, 2, ? 3.
? 1892 *P. waageni* Rothpletz, p. 77, pl. 10, fig. 19.
1897b *P. purdoni* Diener, p. 21, pl. 2, figs. 1 a—d, 2 a—c.
1906 *P. purdoni* Koken, p. 129, text fig.
1915 *P. purdoni* Diener, p. 75, pl. 8, figs. 4, 5.
1916 *P. waageni* Broili, p. 14, pl. 118, figs. 1—5.
1928 *P. purdoni* Hamlet, p. 23, pl. 4, fig. 1; pl. 5, fig. 1.
1931a *Waagenoconcha purdoni* Reed, p. 10, pl. 3, fig. 2.
? 1941 *Waagenoconcha purdoni* Muir-Wood, p. 24, pl. 1, figs. 13 a—b.
1944 *P. (Ruthenia) purdoni paraliensis* Reed, p. 59, pl. 11, fig. 4; pl. 14, figs. 3, 3 a, 4, 4 a, 5.
1944 *P. (Ruthenia) purdoni mirkalanensis* Reed, p. 61, pl. 13, figs. 1, 1 a—c, 2.
1944 *P. (Ruthenia) purdoni prolongata* Reed, p. 62, pl. 13, figs. 3, 4, 4 a, b, 5; pl. 14, figs. 1, 2.
1944 *P. (Ruthenia) purdoni circularis* Reed, p. 63, pl. 13, figs. 6, 6 a—c.
1944 *P. (Ruthenia) purdoni castrensis* Reed, p. 64, pl. 14, figs. 6, 6 a.

This synonymy takes in subspecies and accepts uncritically Reed (1944) without having inspected his types.

Material: Three ventral valves, preserved as internal moulds with part of the external ornament stamped through, and an external mould of a dorsal valve from F 58, and a ventral composite mould of a dorsal valve from F 58, and a ventral composite mould from F 112.

Holotype: Sole specimen figured by Davidson (1862, pl. 2, fig. 5).

Diagnosis: Large *Waagenoconcha* with moderately prominent little incurved massive ventral umbo, gently rounded shoulders and moderately deep sulcus; dorsal valve flat with low fold, spines with short elongated narrow bases.

Dimensions (in *mm.*):

Width	Length	Height	Divergence of Umbonal Shoulders	Sulcal Angle
		Ventral valve — F 112		
30	34	12	70°	28°
		F 58		
37	39	10	60°	25°
53	46	22.5	75°	35°
75	64	24.5	80°	38°
		Dorsal valve		
65	59	9		

Description: The specimens are large and too broken and distorted for measurements to be reliable. The ventral valves are moderately arched, with slightly incurved umbones, prominent posterior shoulders sloping into a little inflated zone near the hinge, and a sulcus. The dorsal valve is almost flat apart from a low median fold, and short trail inclined at 40° to 50° from the visceral disc. Ornament consists of short slightly elongated ridges or pustules 2 to 3 *mm.* long arranged in quincunx on the ventral valve, bearing short spines anteriorly or rarely at mid-length and less than 2 *mm.* apart along rows about 2 *mm.* apart at the anterior margin of the largest specimen. In the next largest specimen the spines are 2.5 *mm.* apart both laterally and radially. On the posterior walls the spines are erect without elongated bases, and a fragment of an external mould leached in acid shows a recumbent narrow base, and spine core inclined gently from the surface within the shell, and then emerging abruptly. About 3 concentric lamellae occur per millimetre.

On the dorsal valve the surface is regularly dimpled and spines are restricted to the anterior disc and trail, with a diameter of 0.3 to 0.5 *mm.* Laterally the pits are very fine, two occurring per millimetre, whereas near the mid-line each pit is 1 *mm.* wide. The ventral valves from F 58 show large rounded gently impressed diductors, marked by longitudinal striae, but adductors are obscured.

Resemblances: The short narrow bases of the spines in the Nepal specimens seem to compare with those typical of *W. purdoni* to judge from comparison with a Kashmir specimen collected by Dr. G. Fuchs, comparable in shape to specimens so identified by Diener (1915), and descriptions by Reed, particularly *purdoni castrensis.* Allowance is made for the larger size of the Nepal specimens. But most of the specimens described by Davidson (1862, p. 31, pl. 2, fig. 5), and Waagen (1884, p. 705, pl. 73, figs. 1—3) from the Salt Range, and Diener (1915, p. 75, pl. 8, figs. 4, 5) from the Zewan beds of Kashmir and from the Central Himalayas (1897 b, p. 21, pl. 2, figs. 1, 2) are apparently narrower shells, with incurved umbo and steep posterior shoulders, and slightly shallower sulcus, and apparently narrower hinge. This is partly at least because of loss of the ears. Also the Nepal specimens are incomplete, and are likely to have been more elongated than would now appear. Certainly a small Kashmir specimen from a fauna just above the *Protoretepora ampla* beds of North Barus (K 16) sent to me by Dr. G. Fuchs is very close in shape and ornament over its umbonal portion.

Muir-Wood (1941) described a non-sulcate transverse specimen from Lachi Series of Sikkim with fine spines, but paid no attention to the nature of the spine-bases. Reed (1931) stressed the narrowness of the spine bases and figured a specimen of typical shape (pl. 3, figs. 2, a). The various Middle and Upper Productus Limestone specimens described in 1944 by Reed are much the same, most having a narrow hinge, though the varieties *mirkalanensis* Reed (1944, pl. 13, figs. 1, 2) and *prolongata* Reed (1944, pl. 13, figs. 3—5; pl. 14, figs. 1, 2) approach the Nepal form. The Upper Productus Limestone variety *castrensis* Reed (1944, p. 64, pl. 14, figs. 6, a) has a wide hinge, with posterior walls more convex in profile. This form was erected to include Diener's specimen from the Central Himalayan Productus Shales. Diener had noted that the hinge of his specimen is wider

than usual, the shell shorter and the umbo broader. REED's figured specimen (pl. 14, fig. 6, a) is here designated lectotype of the subspecies.

These specimens were referred by REED to *Ruthenia* FREDERIKS (1928) and distinguished from *Waagenoconcha* by their swollen spine bases. REED also recognised as *humboldti* shells with very slender spine bases, of which the varieties *silveana* STUCKENBERG (REED, 1944, p. 67, pl. 15, fig. 8; pl. 17, fig. 5; pl. 18, fig. 4) and *xenia* (REED, 1944, p. 68, pl. 16, fig. 6 and pl. 7, fig. 10), both from the Upper Productus Limestone, are similar in general outline and sulcus, and possibly in ornament, but are somewhat smaller.

Specimens from Indonesia have been assigned to *Productus purdoni* by HAMLET (1928, p. 23, pl. 4, fig. 1; pl. 5, fig. 1), together with the specimens figured as *waageni* ROTHPLETZ by BROILI (1916, pl. 114, figs. 2—4). REED (1944, p. 62) commented that the spines are more regular and numerous but this would not seem true from comparison of a specimen I collected from the Upper Productus Limestone of Chhiddru with a plaster duplicate of one of BROILI's specimens (pl. 114, fig. 4). The Indonesian specimens are very like *purdoni* in shape and ornament, but generally have a wider deeper sulcus—perhaps of subspecific importance. LIHAREV (1936, p. 96) considered that *waageni* belonged to *Echinoconchus*, but this is not acceptable.

A puzzling feature is that WAAGEN's figures suggest that the spine tubercles are small and rounded, in contrast to both his text, and figures of other specimens described by other authors, including the original description by DAVIDSON. This may mean that WAAGEN's figures are inaccurate, or that his specimens belong to another species. That there are such specimens in the Salt Range is suggested by a somewhat obscure specimen I collected from the Middle Productus Limestone of Chhiddru.

The flaring posterior margins and shallow sulcus suggest that these Nepal specimens could belong to the complex of specimens which includes *W. abichi* (WAAGEN), rather than *W. purdoni* (DAVIDSON) with its incurved posterior walls and short hinge. The specimens figured as *Productus humboldti* not d'ORBIGNY by DAVIDSON (1862, p. 32, pl. 2, fig. 6; 1863, p. 39, pl. 12, fig. 6) from Kakir Cote and referred by WAAGEN (1884, p. 697, pl. 74, fig. 1—7) to *P. abichi* together with shells from the Middle and Upper Productus Limestone are small transverse little inflated shells, like the very similar *P. serialis* (WAAGEN, 1884, p. 700, pl. 74, fig. 8; pl. 75, figs. 1, 2) from the Upper Productus Limestone. They have well spaced spines about 2 *mm.* apart even close to the umbo, and a long hinge and extended lateral extremities, but are smaller and more transverse with more swollen bases than in the Nepalese specimens and Chiticun specimen of DIENER (1897 a, pl. 3, figs. 8 a—d). The Kashmir specimen figured by DIENER (1899, pl. 1, fig. 8) is similar to *abichi* in shape, with possibly finer spines, and the specimens from the Shan States (DIENER, 1911, p. 32, pl. 5, figs. 1—8) have fine spines and a highly vaulted venter. The Chiticun specimen rather resembles that from F 112. Specimens described by REED (1931 a) are closer to the Nepal shells in their large size and have spines that seem from illustrations to be a little more closely spaced than in WAAGEN's original figures (1.5 *mm.* along a row). Perhaps the closest in shape is *W. abichi densipustulosa* REED (1931 a, p. 8, pl. 2, figs. 1, a, b) and *pseudopalliata* REED (1931 a, p. 9, pl. 2,

figs. 4, 5), REED stressing that the elongated nature of the spine bases as well as the outline of the shells proved affinity with *abichi* rather than *purdoni*. The spine bases of the Nepalese specimens are not as swollen as in either of these forms, or in a third form that is moderately close in shape, *abichi pseudotuberculata* with well spaced tubercles. The spines and shape also agree with *Strophalosia fugax* REED (1931 a, p. 16, pl. 2, figs. 3 a—d), a species of unknown generic affinities, because the cardinal area is obscure, but possibly belonging to *Waagenoconcha*. It is moderately like *abichi consors* REED (1931 a, pl. 1, figs. 1—2) but this has slightly more swollen spine bases.

Productus humboldti of WAAGEN (1884, p. 695, pl. 76, figs. 1—3) from the Middle Productus Limestone has fine spines and shallow sulcus and wide cardinal extremities and so could be related. ROTHPLETZ (1892) referred these to *waageni*. A Basleo specimen so identified by HAMLET (1928, p. 21, pl. 4, fig. 3) proved on inspection at Delft to be a Strophalosiid, with well developed cardinal areas, and flattened ventral umbo. Its spines are somewhat similar in density to those identified as *Aulosteges dalhousi* DAVIDSON, though HAMLET's specimen (pl. 4, fig. 4) is more transverse with a flatter dorsal valve and much higher interarea. Basleo specimens kept at Amsterdam Free University were observed to vary in the concavity of the dorsal valve.

The Dzulfian shell identified as *P. humboldti* by ABICH (1878, pl. 5, figs. 2a to c) and referred to *waageni* by ARTHABER (1900) certainly seems close in shape, with a shallow sulcus and wide hinge as in the Nepal specimens.

Genus *COSTIFERINA* MUIR-WOOD and COOPER (1960)

Type species: *Productus indicus* WAAGEN (1884).

Diagnosis: Large Dictyoclostinae with costae that converge medianly and widen anteriorly into plicae, spines few, in row along hinge and scattered over rest of valve.

Discussion: The Nepal specimens here described have large auricles, and the adductors of the ventral valve extend nearly as far forward as the diductors. MUIR-WOOD and COOPER stressed that adductors did not extend so far forward but they seem to have considered only the posterior adductors and ignored the anterior division.

Costiferina alata n. sp.

Pl. 5, figs. 1, 4, 5; Pl. 6, figs. 1—3; Pl. 7, figs. 3, 5; Pl. 8, fig. 4

cf. 1962 *Dictyoclostus* cf. *indica* TING PEI-CHEN, p. 462, pl. 3, figs. 1 a, b.

Material: Five somewhat broken ventral valves preserved as natural internal moulds, with fragments of the external mould, and external moulds of 10 dorsal valves, with the exterior of the cardinal process sometimes preserved from F 58, and a possible decorticated ventral valve from F 130. All somewhat distorted and broken.

Holotype: Specimen figured in pl. 6, fig. 3, F 58.

Diagnosis: Distinguished from *C. indica* (WAAGEN) by larger size, more alate cardinal extremities and broader plicae anteriorly. Dorsal fold lower.

Dimensions (in *mm.*):

Width	Length	Height	Hinge Width	Diductor Width	Diductor Length	Adductor Width	Adductor Length
			Ventral valve				
45	77	23		19.5	27.5	9.5	28
65	70	22		31	?24	9.5	?31.5
50.5	+50.5	30		?25	?25	13.5	22.5
100	53	25.5		36	19	13.5	?14.5
			Dorsal valve				
40	37.5	17.7	20—35				
+64	63	25	35				
142	+40	+15					
153	46.5	23.5	45				

Description:

External: The specimens are so incomplete and distorted that the dimensions are somewhat misleading. The best preserved specimens are transverse, and extremely alate for productoids. The ventral valves are convex, with the umbo poorly known, but apparently broad and little incurved, and the hinge is marked by a false interarea or ginglymus. A broad evenly concave sulcus arises at or near the tip of the umbo, with its sides diverging anteriorly at 25° in a laterally compressed specimen, and at nearly 60° in a laterally flattened shell — the true angle being somewhere in between. In the dorsal valve the low round-crested fold arises 10 to 12 *mm.* in front of the tiny peaked dorsal umbo, and its sides are enclosed by an angle of usually about 35°, reaching 45° in the largest specimen. Narrow specimens have an almost flat visceral disc, whereas transverse specimens have a gently concave longitudinal profile, and wide short ears, of which the posterior and anterior margins diverge at an angle of 25°, compared with an angle of 40° for those of elongated specimens. They are gently concave near the umbo, and particularly inconspicuous on transverse specimens but become prominent laterally, as highly concave almost tubular alate extremities. The cardinal angle of the cardinal extremities is acute at about 70° for a width of at least 35 *mm.*, but becomes more obtuse laterally with increase in size, to reach an angle of 140° in the widest specimens. Ears of the ventral valves are not so well preserved, but are obviously convex replicas of those of the dorsal valve. They are not defined by a costa from the visceral disc. Around the lateral and anterior margins is a high trail, curving smoothly forward from the profile of the visceral disc in the ventral valve, and clearly geniculate in elongated dorsal valves, and perhaps in wide transverse specimens, though the angularity could have been increased by crushing.

Ornament is not well preserved on the ventral valve. Over a fragment of the exterior it comprises broadly rounded concentric wrinkles about 1 *mm.* across near the umbo, widening to 2 *mm.* in 15 *mm.* from the umbo. They are crossed by 20 to 24 slightly less prominent radial costae, 3 in 3 *mm.* near the umbo, and 3 in 6.5 *mm.* 12 *mm.* further from the umbo. The radial interspaces are broadly concave, whereas those between the concentric wrinkles are sometimes narrow. Pits are formed where the interspaces of the two systems cross. The concentrics fade anteriorly, and are not seen

on the trail, whereas the radials grow in strength to become broad rugae, with crests up to 10 *mm.* apart and 2 *mm.* high. They are finer laterally, 3 occurring in 8 or 9 *mm.* Ornament on the dorsal valve shows a similar pattern, the radial costae expanding from 3 per millimetre at the dorsal umbo to plicae with crests 12 *mm.* apart at the anterior margin. They do not bifurcate, but rarely increase by intercalation laterally beyond the sulcus. The median costae curve towards each other and fuse. Concentrics are fine over the anterior part of the visceral disc, and absent from the trail. Inner ears are almost smooth, apart from traces of low radial and concentric costae, and the outer ears, where they become alate, are generally marked anteriorly by low broad radial costae. A few scattered semi-erect spines lie over the visceral disc of a ventral valve, seeming to arise from the costae and about 0.8 *mm.* in diameter. Similar small spines are seen in a row close to the hinge, and further from the umbo (48 *mm.*) lies a large semi-erect spine nearly two *mm.* in diameter. Anteriorly a large oval erect spine more than 3 *mm.* across arises from the crest of a costa on another fragment, but it is apparent that spines are rare. They are completely absent from the dorsal valve. Two or three growth-lines occur per millimetre near the anterior margin of the largest dorsal valve, with somewhat wavy margins.

The specimen from F 130 is very transverse, with a wide shallow sulcus and about 24 broad low plicae, but is so decorticated that identification is uncertain.

Internal. No teeth are developed in the ventral valve. The diductor muscle scars comprise two simple large rounded shallow impressions scarred by sharply defined longitudinal ridges and incisions 0.7 to 1.0 *mm.* apart, themselves divided by a few secondary longitudinal striae. In some specimens the deepest grooves lie 2 to 3 *mm.* apart, and the intervening ridges are scored by secondary and tertiary grooves with a certain amount of anastomosing and intercalation. On the best preserved internal mould the adductor scars are clearly divided into a broad posterior pair extending back beyond the posterior end of the diductors, and a narrow slightly raised anterior pair, extending not quite as far forward as the diductors. The posterior scars are marked by high ridges directed postero-laterally from the mid-line, fading and branching anteriorly, and the anterior scars are marked by lower transverse ridges which curve concavely forward and inwards into a median groove. The remainder of the visceral disc carries dense fine pits, varying from 1 *mm.* apart in one specimen, to 2 or 3 per millimetre in another, in some specimens aligned, in others apparently random. Over the trails the pits are shallow and inconspicuous.

Little is known of the dorsal valve, but several specimens have a trifid cardinal process, as seen exteriorly, with a high narrow median lobe, and two broader shorter lateral lobes, separated by two wide concave depressions which pass near the hinge into two narrow ridges separated by a groove. Growth-lines parallel to the outer margin are well defined. One specimen shows a deep alveolus on the inner face. Another fragment shows a long narrow median septum and large subquadrate adductors with low productoid ridges.

Resemblances: A close resemblance lies with *Productus indicus* Waagen (1884, p. 687, pl. 70, figs. 1—6; pl. 71, fig. 1), reported from the

Middle and Upper Productus Limestones by WAAGEN, and from Moosakhail and Kafir Cote by DAVIDSON (1862, p. 31, pl. 1, fig. 20), whilst DIENER (1915, p. 66, pl. 6, fig. 15 a—d) described the species from the Zewan beds of Mandakpal. The two agree in essential details of ornament, though full comparison is not possible because of the inadequate preservation of the ventral valves from Nepal. In an internal of a ventral valve figured by WAAGEN (1884, pl. 71, fig. 1), the adductor platform is more posteriorly placed, and not clearly differentiated. This might reflect a difference from the Nepal specimens due to ontogeny or genetic variation but on the other hand there is no proof that the sketch is not inaccurate, like so many others of WAAGEN's figures, as I found in examining for a month the specimens at the Geological Survey of India, Calcutta. A figured internal of a ventral valve in FRECH (1911, pl. 23, fig. 6) from the Middle Productus Limestone seems to have an arrangement comparable to that of Nepal specimens, showing the adductors to extend nearly as far forward as the diductors, and to be subdivided, with basically the same pattern of tangential ridges posteriorly, and transverse ridges anteriorly. Where the Nepal specimens differ is in their very large size, and consequently their better developed auricles, which appear at only a late stage of growth, their transverse outline, and rugae that are wider near the anterior margin, and very low dorsal fold. Some of these differences might seem to be due solely to a later and larger stage of growth attained by the Nepal specimens. But it is noteworthy that both DAVIDSON and WAAGEN stressed that they had figured the largest specimens available to them, yet these are barely half as large as specimens from Nepal. Specimens I have collected in the Salt Range are fully mature, but are more elongated and high with smaller ears than in Nepal specimens, suggesting their ontogeny developed differently. Nevertheless the Nepal specimens may only prove to be a new subspecies. REED (1944, p. 41 ff.) recognised two varieties of *indica*, *paucicostata* for tall enrolled forms with as few as 8 costae each side of the sulcus, including DIENER's specimen, and *subvexa* for a specimen with numerous costae. Neither seem to be of more than varietal or subspecific rank, pending close examination of their occurence and variation.

As far as known no type has yet been chosen for *P. indicus* so the specimen figured by WAAGEN (1884, pl. 70, fig. 2 a—d) is here designated lectotype.

To judge from a specimen figured as *Dictyoclostus* cf. *indica* by TING PEI-CHEN (1962, pl. 3, figs. 1 a, b) it is likely that the Nepal species is represented in Tibet. The Tibetan specimen is smaller than the Nepal specimens, but is larger than Salt Range shells, and has fine posterior and strong anterior ornament, much as in the new form. Unfortunately the auricles are lost, and there is no indication how mature the specimen is. Another smaller specimen figured as *Dictyoclostus* sp. indet. by TING PEI-CHEN (1962, pl. 3, figs. 3 a—d) appears to belong to *Costiferina*, in the *indica-alata* group.

Three congeneric species are easily distinguished from the new form, *C. spiralis* (WAAGEN) of the Lower Productus Limestone by its greater inflation, and finer rugae, though referred to *indica* by FRECH (1911), BROILI (1916), and REED (1934 a), *C. vishnu* from the Middle Productus Limestone by the smooth non-plicate trail, and *C. subcostata* (WAAGEN) from the Middle and Upper Productus Limestones by the finer costae, and other differences. *Productus aratus* WAAGEN (1884, p. 684, pl. 72, figs. 1—2) from

the Upper Productus Limestones has finer costae and a shallow sulcus, but is close to *C. indica*, REED (1931 d, p. 2) suggesting that it is only a variety (or subspecies). More specimens are needed to assess variation.

In respect of the auricles the Nepal specimens approach Word specimens of the Glass Mountains referred to *indicus* by KING (1931, p. 72, pl. 13, figs. 6—9), and renamed *paraindicus* by McKEE (1938). They have been made the type species of *Rugatia* MUIR-WOOD and COOPER (1960).

Another Salt Range species is rather similar in ornament, but distinguished by its very small size. It is the shell named *Productus gratiosus* WAAGEN (1884), referred to *Marginifera* by LIHAREV (1936) and REED (1944), but undoubtedly a *Costiferina*, to judge from examination of a specimen I collected from the Middle Productus Limestones in the Zaluch Nala, Salt Range. Indeed REED (1931 a, p. 3) had earlier commented on the close affinities between this species and *indica*.

Dictyoclostid sp. indet.

Pl. 8, fig. 3

An external mould of a small dorsal valve from F 112 has moderately coarse radial costellae (4 in 5 *mm.* at the anterior margin), crossed by concentric wrinkles (5 in 5 *mm.* anteriorly), a very low median fold, and slightly obtuse cardinal extremities with moderately defined ears. It differs from *Costiferina* in having tubules of matrix suggestive of spine bases, whereas the dorsal valve of *Costiferina* lacks spines.

Genus *LINOPRODUCTUS* CHAO (1927)

Type species: *Productus cora* d'ORBIGNY (1842).

Diagnosis: Subquadrate Linoproductinae, ventral valve ornamented by sinuous costellae, which unit before spine bases, and bifurcate anterior to them, rugae few, limited to ears and lateral margins, spines recumbent or suberect, in one or two rows along the hinge, and erect and scattered over the venter. Dorsal ornament of costae and lamellate growth-lines, spines apparently rare. Ventral adductors elongate, dorsal valve as in MUIR-WOOD and COOPER (1960).

Linoproductus lineatus? (WAAGEN, 1884)

Pl. 4, fig. 6

? 1862 *Productus cora* DAVIDSON, p. 31.
? 1884 *P. lineatus* WAAGEN, p. 673, pl. 66, figs. 1, 2; pl. 67, fig. 3; text-fig. 3.
? 1884 *P. cora* WAAGEN, p. 677, pl. 66, fig. 3; pl. 67, figs. 1, 2.
? 1911 *P. cora* DIENER, p. 19, pl. 3, figs. 3—13.
? 1915 *P. cora* DIENER, p. 65, pl. 6, figs. 13, 14.
cf. 1922 *P. cora* HAYASAKA, p. 68, pl. 5, figs. 3, 4.
cf. 1925 *P. cora lineatus* REED, p. 28, pl. 3, figs. 12—14.
cf. 1927 *Linoproductus lineatus* CHAO, p. 129, pl. 15, figs. 25—27.
? 1931a *Linoproductus lineatus* REED, p. 12.
cf. 1931 *L. lineatus* GRABAU, p. 293, pl. 29, figs. 25—27.
? 1936 *P. cora lineatus* LIHAREV, p. 102, pl. 7, figs. 1—3.
? 1936 *Linoproductus lineatus* DOUGLAS, p. 28, pl. 4, fig. 11.
? 1940a *L. lineatus* RENZ, p. 25, pl. 3, figs. 8, 9.

? 1944 *Productus (Linoproductus) lineatus* REED, p. 54.
? 1944 *P. (Linoproductus) lineatus sirrensis* REED, p. 55, pl. 11, figs. 1, 1 a.
? 1944 *P. (Linoproductus) cora superba* REED, p. 56, pl. 16, figs. 4, 4 a.

Material: A natural internal mould of a ventral valve with a little of the external mould, from F 105.

Lectotype: (Here designated). Specimen figured by WAAGEN (1884, pl. 66, figs. 2 a—d). Kept at Geological Survey of India, Calcutta.

Dimensions (in *mm.*):

Width	Length	Height	Adductor		Diductor		Hinge
			Width	Length	Width	Length	Width
21	34.5	8	?2.3	?10	5	10	?12.5

Description:

External: The specimen is subpentagonal in outline, and elongated, its length a little exaggerated by flattening and longitudinal stretching. The umbo has an angle close to 60°, and is slightly extended beyond the hinge and incurved, the posterior walls are steep and prolonged, and small indistinct ears developed, apparently with obtuse cardinal extremities. A very shallow sulcus traverses the length of the valve with a sinal angle just under 20°. On the fragmentary portion of the external mould, preserved near the posterior lateral margin, there are perhaps 3 to 4 costellae in two millimetres, crossed by about 15 very fine concentric growth lines, with no pronounced rugae. No spines are visible on the external fragment, but a few bases are visible anteriorly on the internal mould, together with traces of costellae, at about 8 in 5 *mm.* anteriorly. A few low rugae are also seen laterally near the posterior third, about 2 per millimetre, and not persisting on to the venter.

Internal: On each side of the umbo the posterior walls are about 2 *mm.* thick, so that the umbonal cavity projects like a beak into the posterior walls. The shell thins to a thickness of 1 *mm.* over the posterior third of the shell-length, and becomes thinner in front and over the venter, so that ornament is partly visible on the inner mould. Muscle scars are somewhat obscure, and the dimensions given only tentative. The adductor platform is raised a millimetre above the floor of the valve and commences in the umbonal cavity, consisting of two round-crested ridges divided by a groove and marked by a few faint longitudinal striae. The diductors to each side are not clearly defined from the adductors nor from the remainder of the shell, and are more or less oval depressions, commencing in front of the posterior end of the adductors, and extending a little anterior to them, with longitudinal grooves and ridges over the surface, crossed by a few wrinkles parallel to the anterior lateral margin of the scars. Details of markings on the remainder of the floor of the valve apart from traces of costellae and spines are obscured by the coarseness of the matrix.

Resemblances: The specimen is possibly a juvenile *L. lineatus* (WAAGEN, 1884) described originally from the Middle and Upper Productus Limestones of the Salt Range, and recognised in the lower Anthracolithic of Spiti by DIENER (1903) and Chitichun (DIENER, 1897 a), as well as numerous other localities. The Nepal specimen is too distorted to be identified with any

confidence, but displays all the features characteristic of young *lineatus* in sulcation, posterior walls, and ornament.

WAAGEN (1884, pl. 66, figs. 1, 2; pl. 67, fig. 3) distinguished his specimens from *Productus cora* d'ORBIGNY by the presence of a sulcus, and DOUGLAS (1936) and REED (1931 a, 1944) have regarded the species as characterised by an elongate, subquadrate outline, shallow ventral sulcus, and moderately defined, non-sinous costellae. Oval non-sulcate shells from much the same horizon were referred by WAAGEN (1884, pl. 66, fig. 3, pl. 67, figs. 1—2) to *P. cora*. In my view these are likely to be conspecific, not on the basis of comparison between the specimens, but from general principles of variation in productoid species, as elaborated in WATERHOUSE (1964 c, pp. 38, 78). Both *L. lineatus sirrensis* REED (1944, p. 55, pl. 11, figs. 1, 1a) and *L. cora superba* REED (1944, pl. 16, figs. 4, 4a) from the Upper Productus Limestone seem to be conspecific, whereas *L. simensis abrupta* REED (1944, pl. 12, figs. 1, 1a) differs considerably, having a flattish disc and trail at right angles, with a suggestion of the funnelled trail seen in some Russian and American forms. *L.* cf. *lahuseni* LIHAREV of REED (1944, pl. 12, figs. 11, 11a, b) is small and narrow, and does not look congeneric, and *L.* cf. *kulikii* of REED (1944, pl. 12, fig. 12) from the Middle Productus Limestone recalls *Anidanthus* in shape and size.

The proposed synonymy is speculative, based on examination of figures rather than specimens, but suggests that *L. lineatus* is a widespread species of the Upper Permian of Asia.

From Chiticun 1 the shells referred to *P. lineatus* by DIENER (1897 a, p. 14, pl. 4, figs. 2—5) might prove to be conspecific, but seem rather small and transverse, and to have unusually well defined ears and slightly coarser costellae than usual. They appear to be more rounded in outline than juvenile *L. lineatus* from the Salt Range, which have long posterior slopes and a somewhat triangular visceral disc, widest near the anterior margin. The Spiti specimen described in 1903 (DIENER, p. 138, pl. 7, fig. 1 a—c) is closer in shape and size, but its preservation as an internal mould makes comparison difficult. As it comes from an older horizon it is not likely to be conspecific. The species is not known from the Productus Shales, but Zewan specimens with extended posterior walls and somewhat triangular appearance, probably because they are not fully grown, were described by DIENER (1915, pl. 6, figs. 13, 14), as *P. cora*. These specimens have very fine ornament to judge from the figures, whereas specimens collected by Dr. B. PLÖCHINGER from the Upper Zewan beds at Palgam (K 25) have costellae twice as coarse as those of Salt Range *L. lineatus*. They differ considerably in appearance from the Syringothyris limestone specimens assigned to *P. cora* by DIENER (1915, pl. 1, figs. 1 a—c; pl. 11, figs. 33 a, b), the older specimens being more compact, elongated and incurved. They are named *L. pollex* n. sp. herein.

Of Lachi specimens figured as *Linoproductus* cf. *cora* by MUIR-WOOD (1941, pl. 1, figs. 4—6) one ventral valve has concentric wrinkles across the venter and another has widely diverging costellae, unlike the ornament typical of *Linoproductus*, but to some extent recalling the ornament typical of *Pseudomarginifera* and *Anidanthus*. Specimens figured as *Productus cora lineata* from the supposed Carboniferous 2.5 miles north of Baroghil Ailak, Chitral, by REED (1925, p. 28, pl. 3, figs. 12—14) have a slightly

more rounded venter than those from the Salt Range, with about 6 costellae in 5 *mm.*, measured from the figure. or of much the same density as in WAAGEN's specimens.

The North Caucasus specimens described by LIHAREV (1936, p. 102, pl.7, figs. 1—3) appear from the figures to lie within the range of variation for the species, agreeing well in shape, and having similar costellae, and only slightly more pronounced ventral sulcus and stronger lateral wrinkles. A Persian specimen figured by DOUGLAS (1936, pl. 4, fig. 11) is likely to be close, though it has well spaced costellae.

The figures of *Productus lineatus* from the Upper Permian of Hupei, China in FRECH (1911, pl. 25, figs. 4 a—c) are not quite adequate to show how close they are to WAAGEN's species, but do indicate a somewhat similar profile for the ventral valve. The specimens figured by CHAO (1927, pl. 15, figs. 25—27) seem close but are hard to assess fully because of their fragmentary nature, and GRABAU (1931, p. 293, pl. 29, figs. 25—27) repeated the figures. Kweichow specimens identified as *Productus cora* by HAYASAKA (1922, pl. 5, figs. 3—4) also seem close, as noted by CHAO (1927).

From Indo-China the Van-yen and Kham-keut specimens referred to *lineatus* by MANSUY (1913 a, pl. 2, fig. 15; pl. 3, fig. 1) look to be moderately similar with fine but somewhat more sinuous costellae, and feebly rounded venter. The beautifully preserved specimen so-identified from the Phnom Ta Kreem (MANSUY, 1914, pl. 6, figs. 2 a—d) is more transverse with a moderately rounded ventral disc, and may not be conspecific.

Figures of Khesi Mansam specimens from Burma allotted (together with *P. lineatus* WAAGEN) to *P. cora* by DIENER (1911) show smallish specimens with ornament and shape identical to the types.

Genus *NEOSPIRIFER* FREDERIKS (1924)

Type species: *Spirifer fasciger* KEYSERLING (1846), designated by FREDERIKS (1926).

Diagnosis: Distinguished from *Spirifer* by fasciculate costae of equal or subequal strength, fine cancellate ornament of radial and concentric lirae, growth-form changes from rounded to transverse (at early maturity) to subrectangular or rounded, delthyrium closed by plate at least in early stages of growth (LIHAREV, 1942). Dental and pleromal plates, ventral adminicula in ventral valve, socket and crural but no adminicular plates in dorsal valve, with low median septum and large cardinal process.

Discussion: The term pleromal plates was applied by CAMPBELL (1959 a) to thickenings on the inner side of the dental plates which fuse posteriorly to form a dental callosity closing or partly closing the umbo. The name adminicula was applied by BROWN (1953) to plates extending up from the floor of the valve to support the dental plates in the ventral valve and crural plates in the dorsal valve. In *Neospirifer* the ventral adminicula are buried in secondary shell, and there are no dorsal adminicula (note this correction to an editorial mistake in WATERHOUSE, 1964 c).

Neospirifer moosakhailensis (DAVIDSON, 1862)

Pl. 8, figs. 1, 2; Pl. 9, figs. 1, 4; Pl. 10, figs. 1, 2

? 1862 *Spirifera moosakhailensis* DAVIDSON, p. 28, pl. 2, figs. 2 a—c.
? 1866 *S. moosakhailensis* DAVIDSON, p. 41, pl. 2, fig. 6.
1867 *S. moosakhailensis* VERCHÈRE, p. 210, pl. 3, figs. 1, 1 a.
1883 *S. musakhailensis* WAAGEN, p. 512, pl. 45, figs. 1—6.
1883 *S. ambiensis* WAAGEN, p. 515, pl. 47, fig. 1.
1897 b *S. moosakhailensis* DIENER, p. 35, pl. 3, figs. 3—4; pl. 4, figs. 1—2; pl. 5, fig. 1.
1897 b *S. aff. fasciger* DIENER, p. 40, pl. 5, figs. 2, 3.
1897 a *S. moosakhailensis* DIENER, p. 43, pl. 6, fig. 8.
1899 *S. musakheylensis* DIENER, p. 63, pl. 5, figs. 3—7.
1899 *Spirifer* sp. ind. aff. *musakheylensis* DIENER, p. 65, pl. 5, fig. 10.
? 1916 *N. fasciger* BROILI, p. 37, pl. 120, figs. 10, 11 (not 12—14); pl. 121, figs. 1—3.
1931 a *Neospirifer warchensis* REED, p. 21, pl. 4, fig. 9.
1931 a *N. fasciger nitiensis* REED, p. 20, pl. 4, figs. 10, 11.
1934 *Spirifer musakheilensis* MERLA, p. 275, pl. 27, fig. 10.
cf. 1934 *Spirifer musakheylensis* ASTRE, p. 74, pl. 8, figs. 17—24.
1941 *N. moosakhailensis* MUIR-WOOD, p. 30, pl. 2, figs. 12, 13.
1944 *N. musakheylensis* REED, p. 196.
1944 *N. musakheylensis humilis* REED, p. 198, pl. 25, fig. 3.
1944 *N. warchensis* REED, p. 198.
cf. 1944 *N. ravana plicatifera* REED, p. 202, pl. 26, figs. 2, a, b; pl. 29, fig. 10.
? 1944 *N. marcoui undata* REED, p. 200, pl. 25, figs. 1, 2, 2 a.
1962 *N. moosakhailensis* TING PEI-CHEN, p. 459, pl. 1, figs. 1—6.
1964 *N. moosakhailensis* WATERHOUSE, p. 132.

Material: Single ventral valves from F 94 and 148, a specimen with valves conjoined from F 108, and two ventral valves, and two specimens with valves conjoined from F 130, and one from F 113. A virtually indeterminable ventral valve from F 129.

Lectotype: Specimen figured by DAVIDSON (1862, pl. 2, fig. 2 a), here designated. Kept at British Museum (Natural History), London.

Diagnosis: Transverse *Neospirifer* with moderately low ventral umbo and moderately high ventral interarea, alate, with rounded anterior-lateral extremities, sulcus shallow and V-shaped in profile posteriorly, wide and more U-shaped anteriorly, fold moderately high and narrow, plicae well developed, costae fine to strong, moderately differentiated, crests rounded, concentric lamellae well developed.

Dimensions (in *mm.*):

Collection Number	Width	Length Ventral	Length Dorsal	Height Ventral	Height Dorsal	Umbonal Angle	Cardinal Angle	Sinal Angle
94	122	+28		11		155°	?35°	
130	140.5	+41		24		?140°		
108	+31.5	31.5	24	9.8	11.2			42°
113	83		50	48	39		120°	20°

Description:

External: As the specimens are broken the shape is best indicated by growth-lines, and reconstruction from various fragments. The smallest specimen appears to be subrhomboidal in outline at a width of about 35 to 40 *mm.*, whereas the larger specimens are very transverse, up to nearly four times as wide as long, but these are incomplete, and are probably less transverse than appears, many *Neospirifer* having extended anterior-

lateral margins at a late stage of growth. In the ventral valve the umbo overhangs the interarea, and is moderately low, with an angle as high as 140° in one specimen from F 130, and probably averaging 130°. The dorsal umbo in F 108 has a wide umbonal angle a little in excess of 160°, and is inconspicuous. The ventral interarea is high and moderately concave, but otherwise not well known, and the delthyrium not exposed. To judge from growth-lines the cardinal extremities are alate with an angle of 40° at a width of about 80 *mm.*, and appear to be obtuse with an angle of 100° at a width of 25 *mm.*, but are otherwise poorly known. A sulcus commences at the ventral umbo, with moderately inclined walls and roundly concave floor like a V in profile with a rounded base. On the small specimen from F 148 the angle seems to be as low as 25°, but the innermost pair of plicae becomes incorporated in other, so the angle approaches 45°,—indeed it reaches 60° to 70° in two, but these are probably crushed. The dorsal fold, preserved best in F 108, is narrow and high, with an abruptly rounded crest, at least posteriorly. On the ventral valve the three inner pairs of plicae are well developed and persistent, and some specimens have a fourth pair. Four pair occur on the small dorsal valve from F 108. They are moderately angular in profile posteriorly, and more rounded in front, and curve outwards as they pass towards the anterior margin. Costae are somewhat differentiated, but secondary and tertiary rapidly become as strong as primary. Three to four costae occur in 5 *mm.* at 20 *mm.* from the umbo on F 94, and on various parts of shells from F 130, compared with 6 to 7 in 5 *mm.* at 15 *mm.* from the umbo in F 148, and on the dorsal valve of F 108 (again at 15 *mm.* or so from the umbo). Crests are rounded, and interspaces perhaps a little narrower than the costae. In spite of poor preservation growth lamellae are still visible, about 5 or 6 per millimetre, arching posteriorly over the costae and anteriorly in interspaces, but only traces of radial fine ornament remain.

The well inflated specimen from F 113 is tentatively considered to be a gerontic member of the species. It has fully rounded anterior-lateral extremities, and a very long sulcal tongue, and thick shell for the ventral valve with plicae and costae no longer visible on the internal mould. The dorsal valve has a very high narrow fold, and three pairs of plicae, the innermost pair lying on the flanks of the fold for the anterior thirds of the length of the valve. Costae have moderately low, well rounded crests, and moderately narrow interspaces. About 4 occur in 5 *mm.* at 25 *mm.* from the umbo on the fold, and at 50 *mm.* laterally, and 3 to 4 in 5 *mm.* near the mid-line at the anterior margin.

Internal: One of the ventral valves from F 130 shows low dental plates diverging anteriorly at 90°, with the adminicula buried in secondary thickening. The muscle field is also partly exposed, and is probably slightly longer than wide, with a very narrow raised median portion not a tenth of the width of the field, and a groove each side in front. The surface of the diductors and the rest of the shell is somewhat worn, and goniophore impressions are visible, radiating from the diductors. Part of the dorsal valve is also exposed. The cardinal process has about a dozen thick blades with finer divisions on myophore face, and is subdivided by a low median cleft, occupied by three or four fine laminae. The base of the process is broad and smooth,

and lies in the same plane as the myophore face. At each side is a small recession, adjoined laterally by low subvertical crural plates, each nearly 12 *mm* long and less than 3 *mm.* high, with a concave inner face, diverging anteriorly at 130°, and converging towards the floor of the valve at about 80°. They are supported from the posterior walls by subhorizontal socket plates. In F 108 a short median septum arises well in front of the cardinal process and extends to about mid-length. Nine turns of the spire, each about 0.8 *mm.* thick, are seen in the specimen from F 113, as well as a median septum extending over the posterior half of the dorsal valve.

Resemblances: In overall appearance these specimens appear to be identical with what may be termed the *moosakhailensis* complex of *Neospirifer*, characterised by transverse outline, moderately high interarea and low umbo, well defined plicae, somewhat V-shaped posteriorly, and rounded in front, well defined costae, usually slightly differentiated posteriorly, the primary being higher than others, and well defined concentric lamellae. Shape varies somewhat, as does coarseness of the costae, and persistence of the plicae. A re-examination of DAVIDSON's types of *moosakhailensis* (DAVIDSON, 1862, 1866) is presented in WATERHOUSE (1964 c, p. 132), though some details of importance, such as the nature of the costae, are not recorded. WAAGEN (1883, pl. 45, figs. 1—6) described several specimens from the Middle and Upper Productus Limestones. On F 3513 (Geological Survey of India, Calcutta) (Fig. 1 of WAAGEN) the plicae do not fade anteriorly as much as suggested in the figure. The primary costae of fig. 2 are high and rounded, and the inner pair of plicae is included in the sulcus. Concentric lamellae are very strongly developed in this specimen. The specimen in fig. 3 from the Middle Productus Limestone has higher plicae on the ventral valve and a raised umbo, and that of fig. 4 from the Upper Productus Limestone has very high primary costae on the dorsal valve, with steep sides and rounded crests. The Lower Productus Limestone specimens referred by WAAGEN (1883, pl. 44, figs. 3—5) to *S. striatus* are moderately close but have lower wider plicae (which *are* present, in spite of the figure) and wider costae and a narrower V-shaped sulcus, perhaps belonging to *N. marcoui* (WAAGEN). I have to hand several specimens which I collected from the Middle Productus Limestone at Chhiddru, Zaluch Nala, and Narmia, and apart from minor variation, all agree moderately well with the specimens described by WAAGEN (DAVIDSON's types were examined so long ago that they no longer remain in my memory). The specimens have well differentiated primary costae, placed on somewhat ridge-crested plicae which are moderately curved in outline, and become lower and more round-crested anteriorly. The costae tend to be round-crested with steep sides, and concentric lamellae are very well developed. By contrast, a specimen, probably akin to *N. marcoui*, from the Lower Productus Limestone of Chhiddru, has lower plicae with more rounded crests, and low broad costae, with rounded crests, and narrow interspaces. Specimens collected from the Lower Productus Limestone in the Zaluch Nala have less rounded, angular-ridged costae.

The Middle Productus Limestone specimen named *N. musakheylensis humilis* REED (1944, p. 198, pl. 25, fig. 3) would seem too poor a specimen to have been named, but is obviously closely allied, with similar tented plicae, in spite of the rounded appearance given by the figure, a slightly

narrower sulcus, and slightly wider costae anteriorly. Compared with WAAGEN's specimens interspaces are narrow.

The Upper Productus Limestone shells named *S. ambiensis* by WAAGEN (1883, pl. 48, figs. 1 a—e) has as noted by WAAGEN a very low interarea, and well developed plicae, and costae which are very low over the umbonal region, possibly because they are worn. In the type, as in Upper Productus *moosakhailensis*, the sulcal plicae are possibly lower than in specimens from the Middle Productus Limestone, but certainty is lacking. Another possible difference lies in the apparently more alate cardinal extremities at an early stage of growth. The difficulty is to assess significance from a few not extremely well preserved specimens. Most authors have considered *ambiensis* to be a variety of or conspecific with *moosakhailensis*, FREDERIKS (1924 b, 1934) referring it to *fasciger* and REED (1944) to DAVIDSON's species.

The small *N. warchensis* REED (1931 a, pl. 4, fig. 9) is a decorticated juvenile shell with costae, plicae, sulcus and fold rather as in *ambiensis*. The innermost bundle plunges into the sulcus sooner than in other specimens seen. It is likely to be a *moosakhailensis* as generally understood, and seems valueless as a species. Unfortunately the Middle and Upper Productus Limestone specimens named *N. warchensis scabrosa* by REED (1944) could not be found when I was at Calcutta.

In some respects *N. ravana plicatifera* REED (1944) invites comparison. The ventral umbo of F 17034 (pl. 26, fig. 2) from the Upper Productus Limestone is more incurved than in *N. ravana*. Cardinal extremities are not alate, and the sulcus appears to be deeper and the fold higher than what is usual for *moosakhailensis*. Compared with the type of *ambiensis* it has a deeper sulcus, but similar plicae and umbo, though the cardinal extremities are not alate at such an early stage. Costae are worn to look like of *ambiensis*, which itself could be worn. The inner sulcal bundles are low as in *ambiensis*, and not as high as in many *moosakhailensis*, but again, those of F 17034 are worn. In the second figured specimen (F 17035, pl. 29, fig. 10) from the Middle Productus Limestone, the costae seem lower than in DAVIDSON's species, but the dorsal valve is obscured posteriorly. The sulcus is shallower than in the other specimen, and with the plicae seems to be virtually the same as in *moosakhailensis*. The fold is narrower, but could be compressed, and the low costae compare best with those of *ambiensis*.

The specimens described as *N. fasciger nitiensis* by REED (1931 a, pl. 4, figs. 10, 11) have high primary costae, well developed bundles, moderately high fold, and strong concentrics as in *moosakhailensis*.

N. marcoui undata REED (1944, pl. 25, figs. 1, 2) from the Lower Productus Limestone is moderately close in appearance. The specimen of fig. 2 was examined, and found to have a sharply raised dorsal fold and sulcus, with more plicae and more alate cardinal extremities than in *marcoui*, although the bundles are low over the umbonal region. Costae vary from fine to broad, and have narrow interspaces. It is rather like *N. ravana plicatifera* but has finer costae, and alate extremities and the inner plicae are lower.

Specimens described by DIENER are particularly close to the Nepal specimens. The transverse specimen from Spiti with wide sulcus in DIENER (1899, pl. 5, fig. 4) is almost identical with specimens from F 130, whilst

the Zewan specimen (pl. 5, fig. 6) of which I have a mould, is very close to the specimen from F 148, apart from a slightly wider sulcus. The Kiunglung specimens of the Productus Shales (DIENER, 1897 b) also tend to be transverse, and the specimen figured in pl. 5, fig. 4 differs from WAAGEN's specimens in that the innermost pair of ventral plicae are not incorporated in the sulcus, and the costae are broader and lower, especially in the dorsal valve. The ventral umbo also is rather low. The transverse specimens from Kiunglung that were referred by DIENER (1897 b, pl. 5, figs. 2, 3) to *Spirifer* sp. aff. *fasciger* are probably conspecific, to judge from inspection at Calcutta. They have a high narrow fold, and costae a little coarser than in *moosakhailensis* but not as rounded as in *marcoui*, being somewhat angular.

Two ventral valves forwarded to me by Dr. G. FUCHS from K 16, a fossil horizon just above the *Protoretepora ampla* beds of North Barus, Kashmir, are moderately transverse with the sulcus not as wide as that of some Nepal or Spiti specimens, but a little wider than that of specimens from the Salt Range, though the width may have been affected by flattening. The plicae do not show outward curvature, the costae seem to be undifferentiated, and low, without steep sides, and the anterior-lateral margins to be much less rounded than usual. Thus the specimens would appear to belong to another species, unless considerably affected by distortion and weathering, but are a little closer to *N. ambiensis* in their alate extremities.

Superficially at least the supposed Upper Carboniferous or Lower Permian specimens from north of Baroghil Ailak, Chitral, described by REED (1925, pl. 6, figs. 1, 2), are close in shape, plication and sulcus, but appear to have stronger costae. They were referred to two taxa by REED, *S. fasciger paucicostulata* REED and *S. fasciger moosakhailensis*, but are likely to be identical. A Tibetian specimen referred to *paucicostulata* by REED (1930, pl. 2, figs. 1, 1 a) has rounded anterior-lateral extremities and strong costae, showing little resemblance to *N. moosakhailensis*.

REED (1944) suggested that the Lachi specimens assigned to DAVIDSON's species by MUIR-WOOD (1941) belong to a distinct variety. According to the figure the innermost pair of plicae seems to be very low, as in the specimens from F 130 and in *N. ambiensis*.

The Tibetian specimens described as *N. moosakhailensis* by TING PEI-CHEN (1962, pl. 1, figs. 1—5) are of considerable interest, for although close to DAVIDSON's specimens, they are moderately well rounded in outline, and not transverse like the Nepal and Himalayan specimens to the south, thus comparing with those described by MUIR-WOOD (1941). They have subdued innermost plicae. *N. kuberensis* looks moderately similar, whereas *N. tibetensis* looks to be of *marcoui* stock.

The moderately elongate specimen figures as *Spirifer fasciger* from the „Fusuline" Limestone of the Shan States by DIENER (1911, pl. 1, figs. 9 a—d) has not been examined at first hand. It has lower plicae than usual for *moosakhailensis* and a rather evenly concave sulcus, but is otherwise close in appearance, though the nature of the costae is not clearly shown in the figures. The Indochinese specimen from Khamkeut of MANSUY (1913 a, pl. 5, fig. 6) also has low plicae, and moderately well developed concentric growth lamellae. It is undoubtedly conspecific with several other *Neospirifer*

from the same locality, though MANSUY (1913 a) preferred to recognise several species. Some of the Mongolian specimens figured by GRABAU (1931, pl. 23, figs. 5—8) are likely to be close, though the specimen in fig. 5 seems to have a sinuate fold, and the specimen of fig. 8 has very coarse costae and few plicae. The specimen in fig. 7 is quite like the Nepal specimens in general appearance. A number of the Russian forms so identified are probably not related, such as the ventral valve recorded from Ussuriland by FREDERIKS (1924 b).

The small Madagascan specimens reported by ASTRE (1934) seem to be allied. They were examined some years ago at Toulouse, and found to have fine costae, not greatly differentiated, although the median costa is slightly higher than its neighbours. Plicae are low and numerous. The umbones of both valves are inconspicuous, particularly that of the dorsal valve, the cardinal extremities bluntly rounded, and the sulcus broadly V-shaped in cross-section, with a concave base, and two inner plicae near the trough. In the moderately large specimen figured by ASTRE (1934, pl. 8, figs. 17, 18) the dental plates are fused for 2 or 3 *mm.* under the umbo, and are discrete anteriorly. The adductor platform is unusually wide, and the diductor scars very long.

Shells referred to the species from Indonesia, and allied species, are discussed in WATERHOUSE (1964 c). According to observations of the types recorded in WATERHOUSE (1964 c), *S. timorensis* MARTIN (1881) and shells assigned to *moosakhailensis* by ROTHPLETZ (1892) from the Indonesian region have more angular costae posteriorly than in the types of DAVIDSON. A specimen from this region recorded by BEYRICH (1865) has not been seen, and the Letti specimen figured by BROILI (1915, pl. 21, fig. 19) is too fragmentary to decipher.

When examining the various specimens from Indonesia, it appeared that the Bitauni specimens of BROILI (1916, pl. 120, figs. 12, 13) are more alate, with slightly stronger costae and more tented plicae, and perhaps a more angular sulcus narrower anteriorly than in the so-called *Spirifer fasciger* from younger beds of the area. According to notes, the Noil Fatoe specimen in BROILI (1916, pl. 121, fig. 2) has low somewhat angular plicae, persisting to the anterior margin, a sulcus somewhat V-shaped in cross-profile posteriorly, becoming evenly concave in front, and fine costae with rounded crests. The Basleo specimens tend to have fine costae with rounded or slightly angular crests, and moderately angular to round-crested plicae, and gently concave sulcus. A plaster duplicate of the Basleo specimen figured in BROILI (1916, pl. 120, fig. 11) has a more evenly concave floor to its sulcus than seen in the specimens from the Middle Productus Limestone, and, to judge from on the unreliable evidence of an internal mould, more rounded plicae.

Examination of the unfigured specimens mentioned by HAMLET (1928) and kept at Delft showed that these specimens have slightly coarser costae than those described by BROILI, with 3 subequal costae in 3.5 *mm.* at 12 *mm.* from the umbo, 3 to 5 costae occuring on a bundle, and 6 at 24 *mm.* from the umbo on some specimens, though others have more numerous costae. Crests are somewhat angular, and the plicae moderately angular in cross-profile near the umbo, becoming rounder and lower anteriorly. The sulcus is rather narrow and deep.

Specimens at Amsterdam showed well developed growth-lines and fine costae, often 'split' into two or even three. Some specimens have a very wide sulcus, recalling the Himalayan specimens.

In summary, the Nepal specimens match well with those from the Himalayas described in various reports by DIENER, and perhaps by MUIR-WOOD, though her specimens are too poorly preserved to allow certainty. They also agree, to judge from figures, with some of the Basleo specimens figured by BROILI (1916) as *fasciger* and do not appear to differ except perhaps subspecifically from the Salt Range Middle and Upper Productus specimens described by WAAGEN and REED. The relationship to DAVIDSON's *moosakhailensis* types is a little more obscure, partly because it is so long since I have seen these types. My Pakistani colleague Mr. FATMI informed me that *N. moosakhailensis* is now though to have possibly come from a Lower Productus Limestone locality. This is not surprising in view of at least a superficial resemblance to Lower Productus forms described as *marcoui undata* REED, or to the Bitauni *N. fasciger* of BROILI (1916), or *N. wairakiensis* WATERHOUSE of New Zealand. Separation from younger specimens may not be easy, for, if DAVIDSON's species is indeed Lower Productus, the younger forms referred to *moosakhailensis* and *ambiensis* possibly descended from it. If the importance of lowness of the cardinal interarea and alate extremities of *N. ambiensis* is discounted it may be possible to refer the younger specimens to *ambiensis*.

Neospirifer ravana (DIENER, 1897 b)

Pl. 9, fig. 2; Pl. 10, fig. 4

1897b *Spirifer ravana* DIENER, p. 34, pl. 3, figs. 1 a—c; 2.
1903 *Spirifer marcoui* DIENER, p. 187, pl. 9, figs. 1 a—d.

Material: Fragments of three specimens with valves conjoined from F 112.

Lectotype: (Here designated). Specimen figured by DIENER (1897 b, pl. 3, figs. 1 a—c). F 6159, kept at Geological Survey of India, Calcutta.

Diagnosis: Large *Neospirifer* with low ventral umbo and moderately strong plicae that persist to the anterior margin. Sulcus deep and fold high.

Dimensions (in *mm.*):

Width	Length Ventral	Length Dorsal	Height Ventral	Height Dorsal	Muscle field Width	Muscle field Length
120		107		38		
121	86	?80	47	41	?39	38

Description:

External: The specimens are huge, and have consequently proved difficult to extract. They are subpentagonal in shape with a prominent umbo, hinge at almost the maximum width of the shell, and slightly obtuse cardinal extremities, forming short ears in one but not the other large specimen. In front of the concave recession that limits the ears the anterior-lateral margin sweeps roundly forward to a very high fold and deep sulcus. In the largest specimen the ventral interarea is about 15 *mm.* high, and weakly

concave under the tip of the umbo, inclined as a whole at about 120° postero-ventrally from the commissure, whereas the dorsal interarea lies more nearly in the plane of the commissure, and is about 8 *mm.* high, and almost flat. Vertical and horizontal striae cover both interareas, and the ventral one is interrupted by a delthyrium with an angle perhaps near 60°—it is not well exposed—and the notothyrium is covered by matrix and shell. Plicae are of moderate height. Over the ventral umbo the innermost pair diverge at about 10° to 15°, and plunge into the sulcus within the posterior third of the shell length, fading in strength as the next pair gains in prominence. Posteriorly they are neither angular nor well rounded, but anteriorly are rounded; whereas the next two pair are broad and well rounded over the anterior half of the shell length. Beyond the third pair plicae are not clearly defind on the large specimen, but a fourth is vaguely indicated on another fragment. In the dorsal valve the plicae are well displayed, a low rounded pair lying on the flanks of the fold for most of the length of the shell, and two pair to each side persisting for over two thirds of the shell length and more angular in profile than those of the ventral valve. There seems to be no plicae over the cardinal extremities of this specimen, but three pair occur on the smallest fragment, and perhaps four pair on the largest specimen. Costae are low and rounded on all specimens as far as they are visible, but cannot be seen over the umbones. The size of costae varies a little in breadth, but not significantly in height. About 7 occur in 5 *mm.* at about 12 *mm.* from the ventral umbo, compared with 5 in 5 *mm.* at 45 *mm.* from the umbo, with at least 12 at this position over the plication bordering the sulcus, and 18 in the sulcus, counting the innermost pair of plicae. Five costae also occur laterally in 5 *mm.* in the obscure fragment. Four to five costae occur in 5 *mm.* at 50 *mm.* from the dorsal umbo, decreasing to 3 in 5 *mm.* at 70 *mm.* from the umbo, both counts made near the mid-line, whereas 5 occur in 5 *mm.* at 50 *mm.* from the umbo laterally. They increase by branching as in other species, but preservation is too poor to make costal diagrams. About 12 costae occur on the plication next to the fold at the anterior margin in the largest specimen, and on a small fragment. The shells are decorticated, and fine surface ornament not preserved.

Internal: The little of the ventral muscle field exposed on one of the large specimens suggests that the adductors are narrow and raised, and that the diductors are lightly striated (5 to 6 per millimetre) with oblique grooves passing from the ridges postero-laterally. Large slightly elongated vascular pits are visible laterally near the cardinal extremities.

The largest specimen has been leached in acid to show low dental plates, concave inwards, and an enormous muscle field, divided posteriorly by a short narrow myophragm. Adductors are poorly differentiated, and perhaps restricted to a narrow band of fine longitudinal striae separated by very narrow interspaces, 3 to 6 per millimetre, and increasing in height anteriorly. This band forms a narrow peaked ridge posteriorly, and becomes a little wider with a more rounded crest in front. To each side and not separated by any groove or ridge are the huge diductors, lightly striated by narrow longitudinal ridges with wide interspaces, about 2 per millimetre, as well as finer striae in places, at 8 to 10 per millimetre. The shell to the sides and in front of the field is confusedly pocked by pits and pustules, with

radiating grooves and ridges laterally, which pass into a zone of fine aligned, pustules, 2 to 3 per millimetre in a somewhat anastomosing pattern, succeeded peripherally by a band nearly 10 *mm.* wide of coarse pustules up to 1 *mm.* apart. These become a little finer peripherally, and give way to an almost smooth band, adjoining the commissure with low radiating ridges and grooves. About 18 turns of the spire, each only about 0.5 *mm.* wide, are exposed in the large fragment from F 112.

Resemblances: The specimens are identical with *N. ravana* (DIENER) in the large size, shape, strong plicae and moderately strong costae. Examination of the type F 6195 at the Geological Survey of India, Calcutta, confirmed the presence of the huge muscle field and deep sulcus and low umbo emphasized by DIENER, and showed that the costae are moderately low with round crests and narrow interspaces. Lateral plicae are very faint. Growth-lines indicate a V-shaped sulcus at mid-length, becoming wider and U-shaped anteriorly.

The specimen F 7465 from the sandstone below the Kuling Shales referred by DIENER (1903, pl. 9, fig. 1 a—d) to *S. marcoui* WAAGEN has a similar low ventral umbo and wide sulcal tongue as in *N. ravana*, and the same alate cardinal extremities as in *N. marcoui* and one Nepal specimen of *N. ravana*—those of the type *ravana* are unknown. The dorsal valve is a little more plicate than in *marcoui*, suggesting an approach to that of *ravana*, though illustrations wrongly imply that the shell is not so plicate. Costae are finer than in *marcoui* or type *ravana*. The dorsal fold is not as high or as narrow as that of *marcoui*, and the ventral umbo less incurved. On the whole it appears likely that the specimen does belong to *N. ravana*. This resolves the problem of the age of the beds, for previous workers have expressed puzzlement at the association of the Lower Permian *N. marcoui* with a number of Upper Permian species.

Specimens from the Productus Shales of Byans and Kiunglung were also compared to *N. ravana* by DIENER (1903, pp. 106, 132), with the comment on their similarity to *marcoui* — presumably the Kuling Sandstone specimen. I have not seen the specimens.

N. ravana plicatifera REED (1944, pl. 26, fig. 2) from the Middle Productus Limestone has a more incurved ventral umbo than in the types of *ravana*, non-alate cardinal extremities, and a narrower dorsal fold. The sulcus is V-shaped, deeper than in *N. marcoui*, and the costae seem to be finer than in *marcoui* or *ravana*, to the extent that the specimens could belong to *N. moosakhailensis*, though the sulcus is deeper and the fold higher than is usual for this form. The second figured specimen (pl. 29, fig. 10) has even stronger plicae, and a shorter sulcal tongue, and high narrow fold. The costae seem lower than in *moosakhailensis*, but REED's specimen is too small to allow adequate comparison with the *ravana* types, of which the umbonal portion is decorticated and partly destroyed. It could even be a descendent of *N. oldhamianus* as the umbo is closer though less incurved than *N. marcoui*, and the sulcus V rather than U-shaped. In many respects this variety of REED's belongs to the *moosakhailensis* complex. The discovery of the specimens from Nepal and the identification of the Kuling specimen should aid a reassessment of the relationship of REED's specimens to *ravana*, hitherto based on rather few poorly preserved specimens.

The sulcus of the Nepal specimens is moderately like that of the Kiunglung *N. moosakhailensis* described by DIENER (1897 b, pl. 4, fig. 2) and DIENER (1899, pl. 5, fig. 3), in which the innermost pair of plicae becomes very low anteriorly and subordinate to the second pair. The dorsal fold is similar posteriorly, but narrower anteriorly, and the umbones more prominent (pl. 5, fig. 3). DIENER's specimens of *N. ravana* have much the same costae, but are less transverse at maturity.

The relationship of *N. ravana* to the other three Salt Range species poses something of a problem. *N. oldhamianus* (WAAGEN) from the Middle Productus Limestone differs in shape, and has rounded cardinal extremities, and low plicae on both valves, with low, broad or fine costae tent-shaped in profile, and a fine ornament mainly of pustules (5 per millimetre) and some growth-lines. In *N. moosakhailensis* the ventral umbo is a little more prominent, and plicae moderately high with tented or high rounded costae. In *N. marcoui* the cardinal extremities are also alate, and the sulcus V-shaped rather than U-shaped in cross-section. Plicae are low on both valves, and the umbo small and pointed, but perhaps larger than that of either of the other two species. Costae are broad or narrow with well rounded crests and noticeably narrow interspaces. In shape *ravana* is rather like *marcoui*, and has a low umbo, rounded costae, and narrow interspaces, but is more plicate, and has a U-shaped sulcus anteriorly, so that if descended from this form, as seems moderately likely, it must have evolved considerably. As far as sulcus and umbo are concerned, *oldhamianus* is closer, whereas *moosakhailensis* has somewhat similar plicae. Further observations are hindered by not having the types available—it is a pity that the Nepal material was not accessible when the types were examined.

Various specimens from the Lower Permian of Asia that have been referred to *N. ravana* are unlikely to be conspecific, the specimens so-named by ČERNYŠEV (1902, pl. 49, figs. 2, 3) having a much more prominent ventral umbo and transverse shape, more as in the *fasciger* complex, whilst the Byro and Wandagee specimens of Western Australia, figured as *S. marcoui* by ETHERIDGE (1914, pl. 1, figs. 5, 6; pl. 2, figs. 8, 9) and referred to *ravana* by STEPANOV (1937) seem much more like *marcoui*, particularly in view of the low plicae and very deep sulcus and high narrow fold. DUNBAR (1955, p. 132) referred Greenland and Spitzbergen shells described as *ravana* by FREBOLD (1931) and WIMAN (1914) to *S. striato-paradoxus* TOULA (1873). They have a shallower sulcus and lower cardinal area than in *ravana*.

Genus *FUSISPIRIFER* n. gen.

Type species: *Spirifer nitiensis* DIENER (1897 b).

Diagnosis: Distinguished from *Neospirifer fasciger* and its allies (which have an umbonal plate across the delthyrium), and *Neospirifer wairakiensis* WATERHOUSE and allies (which lack this plate) by extremely transverse outline throughout ontogeny, and narrow sulcus, and thick delthyrial filling with external pits.

Discussion: In internal details *Spirifer nitiensis* agrees with those described for *Neospirifer*, but appears to have a thick delthyrial plate with two

depressions rather than the thin plate striated with growth-lines of *N. moosakhailensis*. It also differs in its extremely transverse outline, and also in its rather straight-edged, well defined sulcus, which passes above the inner adductors whereas in mature *Neospirifer* the entire muscle field underlies the sulcus. The ventral interarea is high and umbones very low, features which also appear in some species assigned to *Neospirifer*. Growth-lines in the type appear to be non-lamellate, in contrast to *Neospirifer* from the same area. The similarity of *S. nitiensis* to a Sakmarian species *Spirifer byroensis* GLAUERT suggests that the genus extended throughout most of the Permian. Differences from some *Neospirifer* species are subtle but are here taken to imply generic significance, especially in view of the vast host of other species closely similar to *N. fasciger*. The nature of the sulcus and delthyrium are possibly more significant than the transverse shape, which may yet be found to change in late ontogeny, although comparison between the very large senile *F. nitiensis* figured herein (pl. 11, fig. 5), with a large gerontic *Neospirifer* (pl. 9, fig. 2) would suggest that shape remains important throughout ontogeny.

Fusispirifer nitiensis (DIENER, 1897 b)

Pl. 9, fig. 5; Pl. 11, figs. 1, 3, 4; Pl. 12, fig. 1

1897 b *Spirifer nitiensis* DIENER, p. 41, pl. 4, figs. 4, 5 a—e .
1899 *Spirifer* cf. *nitiensis* DIENER, p. 65, pl. 5, fig. 9.
? 1903 *Spirifer nitiensis* DIENER, p. 106, pl. 4, figs. 6 a, b; 7 a, b.
1948 *Neospirifer nitiensis* BRANSON, p. 499

Material: A large specimen with valves conjoined from F 113, and 4 ventral valves from F 58. Specimens somewhat broken and distorted, internal details exposed by leaching in hydrochloric acid.

Lectotype: (Here designated.) Specimen figured by DIENER (1897 b, pl. 4, figs. 5 a—e). Kept at Geological Survey of India, Calcutta.

Diagnosis: Transverse shells with low umbones, narrow sulcus posteriorly, low short plicae and moderately strong costae.

Dimensions (in *mm.*):

Collection Number	Width	Length		Height		Umbonal Angle	Sinal Angle	Cardinal Angle
		Ventral	Dorsal	Ventral	Dorsal			
58	?+120	+41		+12			22°	
113	170—175	63	47.5	27	34		33°	30°
58	?70	20		5		135°	27°	
58	139	31		+13.5		160°	27°	?30°

Collection Number	Shell Width	Muscle field		Adductor Width
		Width	Length	
113	170—175	?37	?37	?6.5
58	?70	15	11.5	2.5
58	+120	21	20	3.5
58	?160	33	24	?8

Description:

External: The specimens are transverse, with low ventral and dorsal umbones, and extremely long hinge. Cardinal extremities are poorly preserved, but faint growth lines suggest they might be somewhat obtuse,

though this is not certain. In the large specimen from F 113 the ventral interarea is over 15 *mm.* high, and curves through about 90°. Similar curvature is seen in the largest specimen from F 58, which has an interarea about 12 *mm.* high. All are marked by horizontal growth striae, and by more or less vertical grooves which vary in definition and attitude. In the smallest specimen from F 58 they are approximately vertical, and rather shallow; in a specimen of intermediate size they are more prominent over the posterior part of the interarea, more or less sinuous in outline, and inclined outwards from the umbo; in the largest specimen they are fainter, and arch outwards. The delthyrium varies in size, but has an angle close to 90° and is closed under the umbo in the two smaller specimens by a thick mass of callus between the adminicular plates, forming an almost flat surface with two depressions side by side near the middle. This thick plate is separated from the dental plates by a narrow groove, and the edges of the dental plates, which form a narrow ridge with a convex crest, are separated from the interarea by another wider groove, sometimes lightly striated by growth lines. In the largest specimen most of this detail has been masked by secondary thickening. The lateral walls are very short, and the anterior margins inclined at about 30° from the hinge, extending with slight forward convexity to the sulcus and fold. These arise at the umbones, and are inconspicuous posteriorly, the sulcus forming a concavity well defined by the two lateral plicae, which beyond mid-length become swallowed as the sulcus widens. The dorsal fold becomes prominent close to the umbo, and is very massive in front, with a gently rounded crest, and no tongue, and to each side the dorsal valve arches ventrally so that the dorsal valve is higher than the ventral. Plicae are very low, with only the innermost pair clearly discernible, though two or three more pair lie laterally. The inner pair persist to about mid-length, the remainder for a much shorter distance, of not even 10 *mm.* Costae are broad and low, with rounded crests and narrow grooved interspaces. On the large ventral valve from F 113 about 4 to 5 occur at 20 *mm.* from the umbo in 5 *mm.*, of even size, except for an apparently massive inner costa at the crest of the innermost pair of plicae. On F 58 the density is only 4 costae in 5 *mm.* at 12 *mm.* from the umbo. The inner costa at the crest of the inner plicae is massive and one arises each side, the outer before the inner, and anteriorly becomes as strong as the middle costa. Lateral bundles possibly have only two costae. A median costa lies in the sulcus, and a lateral one possibly arises each side — details are obscure. Fine radial capillae are well developed, 8 or 9 occurring per millimetre at 2 to 3 *mm.* from the umbo, and about 7 to 8 at 12 *mm.* from the umbo. Concentric growth lines are much finer, 16 occurring per millimetre, 2 to 3 *mm.* from the umbo, and about 10 at 12 *mm.* from the umbo. Plicae also very low on the dorsal valve, with 6 to 7 low costae in 5 *mm.* at 7 *mm.* from the umbo.

Internal: Three specimens show internal features of the ventral valve. One was leached naturally apart from inner shell, and so its exterior is poorly known, the other two were leached in acid. In the natural mould and small leached specimen the dental plates are low, and converge inwards at perhaps 115°, and are supported by low adminicula, diverging to the floor of the valve at 130° to 140° with the outer sides buried in secondary shell. Fine denticles, about 3 per millimetre, are developed along the hinge. A low narrow ridge

runs up the posterior wall of the small specimen, and forms a myophragm over the posterior half of the adductor platform. Two short ridges appear along the mid-line in front, as though there were a ridge in soft tissue, only partly calcified. In the natural mould the myophragm is broad posteriorly, and persists to the anterior margin of the field. In the small specimen the adductors widen steadily to the anterior margin of the field, are smooth posteriorly, and lightly striated longitudinally in front, and apparently separated anteriorly from the diductors by a low ridge. Those of the natural mould are more clearly discernible for they are depressed below the diductors anteriorly, as well as being defined by the low ridge each side, and their maximum width lies near the anterior third of their length, in front of which the sides converge slightly. As well as the longitudinal striae over the anterior two thirds, the posterior rather smooth portion is marked by oblique striae which radiate posteriorly from the myophragm across the posterior diductors, and curve forward laterally. In front, the diductors are marked by ridges which increase by intercalation (2 to 3 per millimetre) and grooves, with traces of finer ridges. In the small specimen the posterior and lateral areas of the diductors are rather smooth, and in both there is a change in inclination along the inner side of the sulcus, close to the adductors. The remainder of the valve floor is smooth apart from fine pustules and anterior costae in the small specimen, but is pocked by a few deep pits posteriorly, and by low more or less radiating grooves and ridges each side of the muscle field.

In the large specimen leached in acid, the teeth are supported by low scapular-shaped dental plates which rest on short adminicula buried in secondary shell. The dental plates diverge to the floor of the valve at 120° to 130° and diverge forwards at about 70° to 80°. There does not seem to be a low umbonal callosity, but this part is damaged. Hinge denticles cannot be clearly discerned, though the vertical striae of the interarea seem to persist for a short distance on to the inner side of the posterior wall. The median quarter of the muscle field is occupied by a slightly raised adductor platform, divided by a median ridge and marked by a few longitudinal ridges and grooves posteriorly, but otherwise smooth. Diductors are faintly marked by longitudinal striae, and the remainder of the valve by low pustules, 2 to 3 per millimetre, as well as low radiating vascular or genital markings. In the large specimen from F 113 the ventral muscle field is poorly known. The hinge is denticulate, 3.5 teeth occurring in 5 *mm.*, and faint vascular markings are seen laterally on the ventral valve, whereas the dorsal interior is almost smooth.

Resemblances: These specimens agree well with *F. nitiensis* (Diener) from Kiunglung, Productus Shales, and Spiti, and perhaps the Lissar Valley shells, though the Nepal specimens are a little too decorticated to allow adequate comparison of the ornament. The shells described by Diener (1903) from the Lissar Valley seem to have better defined plicae than usual, but this may not be significant. The specimens also recall *Spirifer rostalinus auritus* Hosking (1931, pl. 8 A, figs. 4—7) with its similar shape, ventral umbo, sulcus and median sulcal costa, but the plicae appear to be a little stronger on this form, and the anterior margins to become more convex at early maturity. They were treated as a variety of *S. rostalinus*, a relatively long shell, which is highly transverse only at an early stage of growth, before becoming subrectangular in shape at maturity.

Spirifera byroensis GLAUERT (1912) figured by ETHERIDGE (1914, p. 25, pl. 4, fig. 10; pl. 5, fig. 5; pl. 6, figs. 1—5) from the Lyons beds of Mt. Marmion and Byro Station is a similar form, slightly less transverse perhaps, and with finer costae and lower umbones, and lacking the strong median sulcal rib. GLAUERT (1912) in naming the species referred to the specimen figured from Fossil Hill, Wyndham River, by ETHERIDGE (1903, p. 15, pl. 1, fig. 8). This would seem from the figure to lack fine bundled costae, the ornament appearing to consist of fine plicae, much as in the species to which ETHERIDGE referred the shell, *Spirifer lata* MCCOY (1847), though distinguished by sulcal costae. GLAUERT also commented on the absence of ribs in bundles in ETHERIDGE's *S. lata*. Of the types described by GLAUERT, the specimen figured in ETHERIDGE (1914, pl. 6, fig. 1, and 2 if the same specimen) is here designated lectotype.

Neospirifer tomiensis BESNOSSOVA (in SARYČEVA *et al*, 1963, p. 269, pl. 57, figs. 1, 1a) is possibly congeneric. It is less transverse with slightly stronger plicae than in *F. nitiensis*.

Fusispirifer plicatus n. sp.

1928 *Spirifer nitiensis* (not DIENER) BION, p. 24, pl. 1, figs. 1, 2 a, b; pl. 4, figs. 8—13; pl. 5, fig. 9.

Holotype: Specimen figured by BION (1928, pl. 4, figs. 11 a, b), F 13186 (Geological Survey of India, Calcutta).

Diagnosis: The specimens from the Agglomeratic Slate of Kashmir which were referred to *S. nitiensis* by BION (1928) are a little smaller than DIENER's specimens, and distinguished by the more prominent ventral umbo, and stronger plicae, as well as other features. They are more narrowly transverse than *S. byroensis* from Western Australia.

Genus *SPIRIFERELLA* ČERNYŠEV (1902)

Type species: *Spirifer saranae* DE VERNEUIL (1845).

Diagnosis: Oval shells with heavily thickened ventral valve and sculpture of plicae, costae, and pustules, interspaces narrow. Internal details as for *Neospirifer*, ventral adminicula short, buried in secondary shell, delthyrial plate tiny.

Discussion: FREDERIKS (1924 a) erected the genus *Elivina* and OZAKI (1931) the genus *Dienerina* for *Spirifer tibetanus* DIENER, FREDERIKS stating that *tibetanus* is characterised by cancellate rather than pustulose fine ornament. However specimens from Nepal that appear to belong to *tibetanus* have a pustulose ornament, much as in *Spiriferella saranae*. In a recent summary of brachiopod genera IVANOVA in SARYČEVA (1960) recognised the validity of *Elivina* but indicated the type genus as being *S. tibetanus* ČERNYŠEV. It is probable that FREDERIKS interpreted *tibetanus* from ČERNYŠEV's specimens. These are considered to belong to a species not conspecific with *tibetanus*, and, if they are characterised by cancellate ornament, may be placed in a separate genus, although study of Kashmir shells suggests that the distinction between cancellate and pustulose ornament is not consistent even within a single collection.

Spiriferella rajah (SALTER 1865)

Pl. 1, fig. 5; Pl. 3, fig. 2; Pl. 7, figs. 1, 2, 4; Pl. 11, fig. 2; Pl. 12, fig. 2

1865 *Spirifer rajah* SALTER, p. 59, 111.
1866 *S. rajah* DAVIDSON, p. 40, pl. 2, fig. 3.
1899 *S. rajah* DIENER, p. 68, pl. 4, figs. 1—7; pl. 5, fig. 1.
1899 *S.* sp. indet., aff. *rajah*, DIENER, p. 71, pl. 4, fig. 8.
1903 *S. rajah* DIENER, p. 105, 131, 186, pl. 4, figs. 3—5.
1915 *S. rajah* DIENER, p. 86, pl. 9, figs. 5, 6.
1941 *Spiriferella rajah* MUIR-WOOD, p. 36, pl. 2, figs. 2, 3; 9—11.

(Possible subspecies are omitted)

Material: About 14 ventral valves from F 117, showing internal detail, but a little decorticated, and with the thin margins lost. A decorticated ventral valve from F 147. A dorsal valve from F 58 might be conspecific.

Lectotype: When in England some years ago I failed to see the type specimen or specimens named by SALTER, but was informed that they were kept at Oxford.

Diagnosis: Ventral valve elongated, domed, heavily thickened, with incurved massive umbo and narrow cardinal extremities, plicae strong, interspaces narrow, sulcus comparatively shallow, its angle diminishing anteriorly. Distinguished from typical *rajah* by smaller cardinal extremities and fewer costae.

Dimensions (in *mm.*): Ventral Valves From F 117.

Width	Length	Height	Umbonal Angle	Sinal Angle	Cardinal Angle	Muscle field Width	Muscle field Length	Adductors Width
24		7.3	110°	20°	150°	9		
21	35	12.5	80°	20—12°	115°	8.5	11.8	
17.5	34	20.5						
22	45	18.5	70°	20— 8°	120°			
23.8	50.5	20	75°	22— 5°	115°			
29.5	39	24.5	85°	18—12°	70°			
31	40	18				11.5	14.5	
26.5	34	10.5	120°	22—15°		12.2	11.5	3.2
31	39.5	15.5	90°	20—10°	140°			
40.2	54	20	110°	?20— ?5°	130°	16.2	15	3.7

(Under sinal angle, the first figure indicates the angle at quarter length, the second at the anterior margin)

Description:

External: The measurements apply only to the thickened posterior part of the shell, the thin part around the commissure having been lost, so that the specimens would have been a little wider and longer, and considerably higher. They have also been distorted at various angles, elongated or crushed flat, and various angles diminished or exaggerated. It also seems that some of the variation is original, and that some specimens were more elongated, with narrower umbones, than others. All are characterised by a somewhat elongated outline, with a massive incurved umbo, and high posterior walls sweeping out to very narrow cardinal extremities. In front of the hinge the shell is well rounded, with the maximum width usually in front of mid-length. Interareas are very high, and curve in large specimens

through more than 90°. They are marked by vertical and transverse striae, and interrupted for the median third of the length by a large delthyrium, of which the sides converge posteriorly by about 30° before arching together under the umbo. As now preserved the cardinal extremities are obtusely rounded, except for one specimen, which has a tiny acute ear. Growth lines suggest that up to a width of least 20 *mm.*, up to 30 *mm.*, the extremities are obtuse, and that as the shell further increases in size, they become acute. In cross profile the sulcus is like a V with a rounded base, and though its sides widen from umbo to anterior margin, the angle diminishes forward, so that the angle between umbo and sulcal edges at the anterior margin is much less than between umbo and the margin at a half or quarter length. The fold of the specimen from F 58 is narrow with a shallow interspace between two costae, but no marked median cleft. Ventral ornament consists of four or five pairs of plicae increasing in height to the anterior margin, and separated by narrower grooved interspaces. A median costa extends for most of the length of the sulcus. On most shells the primary costa on the innermost pair of plicae coincides posteriorly with the plication, and then branches into two within 10 *mm.* of the umbonal tip, and the outer costa again branches at about 20 *mm.* from the umbo. The inner may branch again at about 30 *mm.* Two or three low costae may also develop on the adjoining plication, and the outer pairs usually remain non-costate. Beyond the plicae the lateral shell is smooth. Its surface is worn so that pustules have been lost, and only a few traces of growth-lines remain. One leached specimen has traces of radial (7 per millimetre) and transverse striae, possibly interrupted and pustulose, but preservation is too poor to allow certainty. Another, although riddled by tubes from boring organisms, has fine pustules (about 14 per millimetre) in concentric rows of 3 to 4 per millimetre.

Four pair of plicae occur on the dorsal valve, and a strong costa arises close to the umbo each side of the fold.

Internal: In several specimens the floor of the shell under the delthyrium is occupied by a broad, rounded callosity, without anterior fork or median groove, but the largest specimen has a double callosity—separated by a shallow median groove which is deepest posteriorly, and persists anteriorly beyond the umbonal callosities (which stop just in front of the teeth) as far as the adductor platform. Another specimen leached in hydrochloric acid has a median and two low lateral ridges. Under the umbo of these two specimens lies a tiny plate, above the floor of the delthyrium, and attached to the posterior walls and dental plates to each side. Teeth are supported by scapular-shaped long dental plates which converge inwards at about 100° to 110°, with a concave inner face in some specimens, and supported by adminicula which, largely buried in secondary shell, diverge to the floor of the valve at about 40°, and extend little beyond the teeth. The muscle field lies immediately in front, between the adminicula in most specimens, but also outside of it in the largest specimen. The adductor platform is narrow, slightly raised, and divided from the diductors by a groove. It is subdivided posteriorly in the largest and leached specimens by a short ridge which passes forward from the groove dividing the umbonal callosity, and by a median groove in other specimens. The surface is convex and

is marked by one or two longitudinal striae in most specimens and finely striated in the leached internal mould. To each side the diductor scar is marked by three shallow longitudinal grooves, and a few growth wrinkles parallel to the anterior margin, as well as fine striations in the leached internal mould.

The muscle field is raised anteriorly by resting on a ramp-like ridge under the sulcus, and this ridge passes to the anterior margin, with a narrow crest and concave sides. Large pustules lie over the remainder of the valve, at about 5 to 7 in 5 *mm.*

The shell of the dorsal valve is less than 0.5 *mm.* thick, compared with a thickness of 14 *mm.* for the largest ventral valve.

Resemblances: These specimens probably belong to *Spiriferella rajah* of SALTER (1865), having the same massive incurved ventral umbo, shallow sulcus, and narrow interspaces between wide gently convex plicae, and no cleft in the dorsal field. In the large specimen figured by DAVIDSON, and several others, the sulcus, though widening, has a diminishing sinal angle, just as in the Nepal specimens. Of generic importance is the observation at Calcutta of pustules on a specimen figured by DIENER from the Zewan beds. In the specimen figured in 1915 (pl. 9, fig. 5) the dorsal valve has strong concentric lamellae (3 to 6 per millimetre) with low pustules (3 to 4 per millimetre) along their posterior upper surface. The ventral valve (pl. 9, fig. 6) has interleaved concentric lamellae, and about 8 pustules per millimetre, of definitely smaller size.

The Nepal specimens differ in two respects. They apparently have a slightly narrower hinge, and definitely have fewer costae, in contrast to the specimens figured as *S. rajah* by DAVIDSON (1866, pl. 2, fig. 3) and most of the specimens described by DIENER (1899, pl. 4, figs. 1—7; pl. 5, fig. 1; 1903, pl. 4, figs. 3—5; 1915, pl. 9, figs. 5—6), and BROILI (1916, pl. 119, figs. 1, 2, 4, 5, 7). The differences are consistent enough to allow recognition of a minor geographic subspecies for the Nepal specimens, distinct from those of Kashmir, Spiti and Lissar Valley a little to the west but I defer taking this step until relationships with *vercherei* DE VERNEUIL, *vihiana* DAVIDSON and *interplicata* ROTHPLETZ are more fully explored. It seems that the Nepal specimens are much more closely related to *S. rajah* than these taxa, which might however be regarded as subspecies of *rajah*, particularly ROTHPLETZ's form. The specimens figured as *S. rajah* by MUIR-WOOD (1941) are poorly preserved and poorly figured, but are possibly comparable to the Nepalese shells.

The difference between the Nepal specimens and DAVIDSON's types are not very significant. It is noteworthy that two dorsal valves figured from Kashmir by DIENER as *S. rajah* (1899, pl. 4, fig. 2; 1915, pl. 9, fig. 5) and *Spirifer* sp. indet. aff. *S. rajah* (1899, pl. 4, fig. 8) have few costae. At least two *Spiriferella* clusters vary considerably in the amount of costation. For instance most of the Basleo specimens described by BROILI (1916, pl. 119, figs. 1, 2, 4, 5, 7, 9) have numerous costae, but several other specimens (pl. 118, fig. 19; pl. 119, figs. 3, ?6, 8, 11) have few costae, and a few internals are figured, with the costae not displayed (pl. 120, figs. 1—6). However most of the apparently non-costate specimens are all rather small, and could have developed costae at a later stage of growth. Nevertheless there is

some variation of costation, for a plaster duplicate of the specimen figured by BROILI (1916, pl. 119, fig. 4), kindly presented from the University at Amsterdam, clearly shows the presence of costae close to the umbo, well before the size reached by the non-costate specimen of fig. 8. The variability in ornament, and especially the greater depth of the sulcus and slightly less rounded plicae of these Basleo forms suggest another distinct geographic race, and it is interesting to note that BROILI (1916, pl. 118, fig. 11) figured cancellate ornament without pustules. A median cleft is developed in the fold, unlike the Nepal, DAVIDSON's or MUIR-WOOD's specimens, but like some of DIENER's shells.

Perhaps the Timor specimens are identical with the *S. interplicata* ROTHPLETZ (1892) from Ajer Mati, in which case they could be treated as *S. rajah interplicata*. Unfortunately the types of *interplicata* are so small that adequate comparison is very difficult, though it may be noted that the costae curve outwards a little more than in the specimen figured by BROILI (1916, pl. 119, fig. 4). When examining the ROTHPLETZ specimens in 1957 I considered that there was no apparent difference from BROILI's *S. rajah*, especially in the dorsal valve. The two specimens are small, and probably immature, despite the fact that the cardinal interarea ends abruptly, rather than tapers to a point. Four costae were counted in the figured specimen on a plication at 18 *mm.* from the umbo, and the delthyrial angle was measured as 90° to 100°. The other (unfigured) specimen is non-costate.

Another group of *Spiriferella* with even more variation in ornament, though from single localities, was referred to various taxa by GRABAU (1931) in describing occurrences from Mongolia. Two costate shells were referred to *rajah* (1931, pl. 22, figs. 1, 2) but one is very fragmentary, and the other an internal mould, difficult to compare with the material preserved as shells from Kashmir and Spiti. Associated less costate and non-costate shells were referred to *S. salteri* ČERNYŠEV var *typica*, and var *wimani* and *var simplex*, and to *S. keilhavi* (von BUCH) and *S. keilhaviiformis* FREDERIKS, all from the fossil locality F 1209 of the *Spiriferella* bed. To judge from illustrations most of these are likely to be conspecific, and although there may be value in distinguishing morphological varieties, they are no more than varieties. Certainly GRABAU's reference of some non or sparsely costate *Spiriferella* described by DIENER and BROILI to varieties of a species different from associated *rajah* seems unwarranted.

In a work not available in New Zealand DE VERNEUIL (1867) described from Barus Valley *Spiriferella vercherei*, distinguished from *S. rajah* of Spiti by its few costae. DIENER (1899) stated that the absence of costae was due to weathering, and followed by MUIR-WOOD (1941), synonymised the Barus Valley form with *rajah*. It is certainly clear from DIENER's illustrations that at least some Barus Valley specimens are costate (1899, pl. 4, fig. 1) and some dorsal valves from Spiti and Mandakpal, not particularly weathered for they still show growth-lines, have few costae (see above). REED (1925) indeed also discounted the effect of weathering, and considered DE VERNEUIL's taxon to be valid.

A number of specimens sent to me from K 13, the *Spirifer rajah* horizon at Mandakpal, Kashmir by Dr. FUCHS possibly belong to *vercherei* and almost certainly agree with *S. vihiana* DAVIDSON (1866). They have wide hinges

and a transverse shape, two or three more pairs of plicae than in the Nepal *S. rajah* and a cancellate fine surface ornament with few pustules, thus differing at least to subspecific level. Costae are absent or restricted to the anterior margin, or to the inner plications. A number have a median sulcal plication, and strong subplication each side of the sulcus along the inner edge of the first pair of plicae, just as in the Tibetan shell referred by TING PEI-CHEN (1962, p. 462, pl. 3, figs. 2 a—c) to *S. salteri*. The sulcus of the Tibetan shell is similar to that of the K 13 shells, but the hinge narrower and plicae fewer. The Tibetan specimen differs from *S. salteri* figured by ČERNYŠEV (1902, pl. 12, figs. 5, 6) in having a lower ventral interarea, narrower hinge and sulcus and fewer costae.

Lower Permian Chitral specimens assigned by REED (1925) to *S. rajah* and *S. vercherei* vary in costation but are likely to be one species, even though the "*rajah*" shells have wider sulcus, lower plicae and more costae posteriorly than shells referred to *vercherei*. The large number of plicae (seven pairs), and rather narrow sulcus that seems to be a little wider than in some specimens of *S. rajah* suggests that they are slightly closer to *vercherei*. Absence of the hinge and dorsal valve makes further comparison difficult. They are moderately close to the Nepal specimens in incurved umbo and massive posterior shoulders, but seem to have a more clearly defined median costa, a narrower ventral umbo, and narrower delthyium, and slightly wider sulcus and more numerous plicae. According to REED the ornament is cancellate, with pustules.

A Salt Range specimen recorded as *vercherei* by REED (1931 a, pl. 4, fig. 12) is a small decorticated specimen with a wider sulcus than in the Chitral "*vercherei*", and so like that of Chitral *S.* "*rajah*", but a little deeper. The shell is wider and the plicae more widely diverging and of slightly greater strength compared with Chitral "*rajah*".

The specimen compared to *vercherei* by DIENER (1915, pl. 9, fig. 10) was examined at Calcutta, and found to have a punctate shell.

Of other references to *S. rajah*, I have not seen the work by FREDERIKS (1916) recording *S. rajah* specimens which, coming from the Lower Permian, are unlikely to be conspecific. The Indochinese specimens described by MANSUY (1912, p. 41, pl. 8, figs. 10 a—b) from the Lower Permian are probably not conspecific, and the specimen compared in 1916 (MANSUY, pl. 3, fig. 7) is too poorly preserved to decipher.

The Yunnan specimen referred by REED (1927, pl. 14, fig. 8) to *S. rajah* is closely costate, and unlikely to be closely related.

According to MUIR-WOOD (1941, p. 40) a specimen figured by EVEREST (1833, p. 2, fig. 23) as *Producta* and emended by J. de C. SOWERBY (1833, p. 278) to *Spirifer striatus* is probably *S. rajah*.

Spiriferella tibetana (DIENER, 1897 a)

Pl. 2, fig. 2; Pl. 9, fig. 3; Pl. 12, figs. 3, 4; Pl. 13, figs. 1, 2, 4, 5.

1897 a *Spirifer tibetanus* DIENER, p. 45, pl. 6, figs. 1—7.
1903 *S. tibetanus* DIENER, p. 17, 81.
cf. 1928 *S. tibetanus* HAMLET, p. 37, pl. 7, figs. 1, 2.
? cf. 1934 *S. tibetanus tenuisulcatus* MERLA, p. 273, pl. 26, figs. 14—21.

Material: Nine ventral valves from F 108, five or six ventral valves and a dorsal valve from F 130, rather squashed.

Lectotype: (Here designated.) Specimen figured by DIENER (1897 a, pl. 6, figs. 1 a—e), F 6112, Geological Survey of India, Calcutta.

Diagnosis: Transverse to elongate shells with prolonged narrow ventral umbo, narrow cardinal extremities, deep wide sulcus and well defined plicae with moderately deep interspaces, dorsal fold with median cleft.

Dimensions (in *mm.*):

Width	Length	Height	Umbonal Angle	Sinal Angle	Cardinal Angle *)
		Ventral Valves F 58			
11.5	13	?5	70°	25°	100°
25	25	11.5	75°	25°	120°
35	44	13.5	95°	20°	150°
36	?30	10.5			150°
36	35.5	11	70°	22°	
33	41	11	45°	24°	?140°
47	29	11.5	110°	30°	
52	33	13.5	70°	27°	
		Ventral Valves F 130			
40	59	13	80°	18°	
55	33	13	130°	22°	
		Dorsal Valve			
				Fold	
39	73	6.5	?130°	14°	

Description:

External: As the measurements show, the shells appear to vary considerably in relative length and height, and although many of the differences may be ascribed to distortion, or breakage and loss of the anterior little thickened margin, it appears that some of the variation is original—both the very elongated and especially the largest transverse specimen from F 108 seeming to be relatively complete, and not very distorted. Part of the variation is due to the differing amount of incurvature of the ventral umbo, that of the elongated specimen for instance being much less incurved than that of the large transverse specimen. In most specimens the umbo is somewhat attenuated and usually narrow, and the posterior walls are concave in outline. Cardinal extremities are also narrow, non-alate and consistently obtuse. The cardinal interarea is poorly exposed, but is obviously highly curved. The maximum width of the shell lies just in front of mid-length. The only dorsal valve available has been squashed, but seems to have a low umbo extending a little beyond the hinge. The sulcus is moderately deep, and V-shaped in cross-profile, with a concave base, the trans-sulcal angle varying from 130° in the largest specimen to 120° in the elongated specimen,

*) Measured between hinge and lateral margin.

and it widens steadily forward at much the same angle throughout its length. The fold appears to be comparatively low and broad, but is flattened, and has a deep median cleft. There are 12 to 16 plicae on the ventral valves, moderately straight in outline with well rounded varying to somewhat flattened crests, and narrow but moderately well defined interspaces. Within about 5 *mm.* of the umbo the innermost pair of plicae subdivide, and the inner branch forms a subplication in the large transverse shell, and a strong costa in the elongated specimen. Costae vary. In the transverse and several elongated specimens a narrow median sulcal costa arises just in front of the umbo, whereas it seems to be restricted to the anterior margin in the very long shell, though this could be due to weathering. Apart from the innermost branch, the plicae remain non-costate for nearly 20 *mm.*, and then the inner four or sometimes five pairs subdivide usually into three costae of similar height and width. In one elongated specimen the lateral plicae are not costate, and the primary costa, after forming the inner branch, branches again at 8 *mm.* from the umbo, and the inner one branches at 10 *mm.* The outermost of these costae branches again just at the anterior margin, together with the adjoining two pairs of plicae at a distance of over 25 *mm.* from the umbo. In this specimen the costae are raised with flattened crests, and the interspaces deep. In the best preserved of the specimens from F 130, the sulcus has a median costa, and the inner branch forms a prominent subplication, which in one specimen branches again at about 10 *mm.* from the umbo. The surface is rather worn, but seems to show traces of fine costae, possibly up to five per plication anteriorly, a little finer than in the shells from 108, whilst a large fragment has about 9 costae on a plication at about 80 *mm.* from the umbo. At the outermost cardinal extremities the shells appear to lack costae. Growth-steps are present at intervals. The fold of the dorsal valve from F 130 is subdivided by a deep median cleft, which commences at the dorsal umbo. At about 45 *mm.* from the umbo there are six costae, though the pattern is complicated next to the fold. Laterally the shell seems to be smooth, but is worn.

On parts of some shells from F 108 are regularly spaced pustules, about 6 per millimetre, and a finer pattern of tiny dense pustules, about 14 per millimetre. They are possibly due to shell structure, for the surface seems to be somewhat worn. A few growth-steps occur at intervals. On the other hand the anterior part of the dorsal valve from F 130 has more convincing pustules, radially aligned in rows, about 2 per millimetre with about 3 in 1 *mm.* along a row, divided by interspaces between growth lamellae. The shell is a little worn over the crests of the plicae, where the pustules are obliterated, so they do not seem to be the product of weathering. Dense pits and pustules, probably caused by weathering, are seen on the ventral valves from this locality.

Resemblances: The specimens from F 108 are particularly close to the original Chitichun specimens described by Diener (1897 a) in their narrow extended ventral umbo, rounded cardinal extremities, deep wide sulcus, median sulcal costa and prominent inner branch, and arrangement of plicae and costae. The elongated Nepal specimens are closest in shape, there being few transverse shells in Diener's original lot. The specimens from F 130 have somewhat fine costae, but the dorsal fold is cleft medianly as in Diener's

specimens. The species is readily distinguished from *S. rajah* by the more elongated ventral umbo, less massive posterior walls, rounded cardinal extremities, deeper sulcus, wider deeper interspaces, cleft dorsal fold, different costal pattern, and other details.

The Lower Permian specimens assigned to this species by ČERNYŠEV (1902, pl. 7, figs. 2—6) are small globular specimens with a similar dorsal cleft, and numerous plicae but tend to have the position of maximum width more posteriorly placed, the ventral umbo more massive, and the costae, especially within the sulcus and on the fold, arising closer to the umbones. The resemblance to DIENER's form seems to be only superficial. They have a much more angular sulcus than in DIENER's specimens, and, having been assigned to *Elivina* FREDERIKS, presumably have a cancellate ornament without pustules. Nor do Upper Carboniferous specimens described by OZAKI (1931) from Japan appear to be related. Two specimens figured from the *Schwagerina princeps* beds of Laos by MANSUY (1913 a, pl. 5, fig. 11; pl. 6, figs. 1 a—d) have an angular sulcus also, and a moderately extended ventral umbo, this being the main similarity to DIENER's species. A median cleft does not seem to be developed in the fold of fig. 1 b, c, but is present in a dorsal valve from the same locality that was assigned to *S. interplicata* of ROTHPLETZ. The arrangement of costae differs considerably from that of *S. tibetana*.

On the other hand the Basleo specimens described by HAMLET (1928) appear to be closely allied, having a similar outline, deep sulcus, pointed extended ventral umbo, and numerous plicae. Costae are not developed over the plicae, but the specimens are small, a factor hindering complete identification. The dorsal fold seems to have a median cleft, and the sulcus a median costa, though the figures are not completely clear on this point. HAMLET (1928, p. 37) suggested that *Spirifer kupangensis* BEYRICH (1865, pl. 1, fig. 6), listed by ROTHPLETZ (1892, p. 79) and refigured by FRECH and NOETLING (1902, p. 589) might be conspecific, but it lacks a median sulcal costa, and has two strong lateral sulcal costae arising very close to the umbo. Perhaps HAMLET's specimens belong to this form — it is difficult to tell from the few poor illustrations and certainly HAMLET's specimens have less massive shoulders than in *S. kupangensis*.

MUIR-WOOD (1941, p. 40) referred the Letti specimens of BROILI (1915, pl. 21, figs. 11 a, b; 17 a, b, 18) to *S. tibetanus*. To judge from the illustrations they might be allied in their extended ventral umbo and deep sulcus, and non-costate lateral plicae, and median sulcal costa, but seem to have a different ornament with many costae in the sulcus and fold and few laterally. One specimen (fig. 17 b) lacks fold costae, or median cleft. A Tibetan fragment recorded by REED (1930, p. 30, pl. 2, fig. 15) is too incomplete to interpret, at least from the figure. A specimen named *Spirifer tibetanus lata* by MERLA (1934, p. 21, fig. 25) is possibly close, having an extended umbo, a median and strong lateral costae in the sulcus, which arise very close to the umbo. Innermost plicae seem a little wider than usual, but the specimen could be within the range of variation, though the small size prevents a confident assessment. Narrower specimens were referred to the variety *occidentalis* SCHELLWIEN (not WHITEAVES) by MERLA (1934, pl. 21, figs. 20—22). Whilst moderately similar in outline, and with a dorsal median cleft they have posterior walls that are convex rather than concave in outline. The work

in which RENZ (1940 b, 187, p. pl. 6, figs. 4 a—b; 8 a—d) assigned further specimens to *S. tibetanus occidentalis* is not available in New Zealand.

The Trogkofel specimens so-named by SCHELLWIEN (1900, pl. 11, figs. 10—13) are certainly similar in general outline to *tibetana*, but costae are restricted to the fold and sulcus, FREDERIKS (1932) referring the form to *Eliva lyra*.

Upper Permian specimens named *S. tibetanus tenuisulcatus* MERLA (1934) are figured as having an unusually strong median costa, and the innermost pair of plicae branches close to the umbo and the posterior walls are less concave in outline than DIENER's types, approaching MERLA's *occidentalis*. Like many other specimens described by MERLA, these appear to be juveniles, and so are very difficult to identify with confidence.

Genus *MARTINIOPSIS* (WAAGEN, 1883)

Type species: *Martiniopsis inflata* WAAGEN (1883), designated by ETHERIDGE (1892, p. 238).

Diagnosis: Brachythyrid shells with shallow or no ventral sulcus, low or no fold, no plicae, fine surface ornament of rounded pits or short grooves or ridges in quincunx. Ventral valve with umbonal callosity, dental and adminicular plates, no median septum, dorsal valve with socket, crural and adminicular plates, transverse spiralia, cardinal process and low median septum. Shell pierced by taleolae.

Discussion: Type specimens of various species from the Salt Range and Himalayas have been recently revised by WATERHOUSE (1965). It was shown that differences from Campbell's genus *Ingelarella* and SAHNI and SRIVASTAVA's genus *Ambikella* are very slight, apparently depending on the fineness of the surface ornament. The emphasis placed by BROWN (1953) and CAMPBELL (1959 a) on the absence of a sulcus is incorrect, several species having a shallow sulcus.

Martiniopsis sp,

Pl. 14, fig. 1

Material: A broken natural internal mould of a ventral valve with part of the external mould from F 105.

Diagnosis: Moderately large for the genus, transverse with long hinge and shallow sulcus, widening anteriorly, low fold, pitted fine ornament.

Dimensions (in *mm.*):

Width	Length	Height	Adminicula Length	Adminicula Apart	Muscle field Length	Adductor Width
34 ?	28	9.5	6	3.8	8.8	0.8

External: Although the specimen is broken and obliquely distorted, it appears to have originally transverse, and moderately inflated, but the lateral and anterior margins are destroyed, so that this lacks certainty. Posterior walls are moderately high and concave in outline, the umbo now narrow and prominent due to distortion, and the hinge long with an unusually well developed interarea up to 2 *mm.* high, gently concave under the umbo,

and marked by strong subvertical grooves, some of which fork anteriorly. The delthyrial angle is only 30°, but has been narrowed by crushing. A shallow sulcus is present, arising close to the umbo, and persisting to the anterior margin with an angle of less than 10°. Fine surface ornament is somewhat obscured by shearing, but appears to consist of small pits and short surface grooves up to about 0.15 *mm.* long, about 8 to 10 per millimetre, but difficult to measure with accuracy because of masking by white crystals, and an oblique shear pattern. In places the ornament seems to comprise ridges or mounds rather than pits.

Internal: A long umbonal callosity is developed with an eccentric ridge on one side. Dental plates are close-set, and supported by short adminicula which diverge anteriorly and to the floor of the valve. It is possible that their posterior part has been lost with some of the muscle field, for they seem to be unusually short and the posterior wall unusually thick with over 3 *mm.* space between the internal and external moulds. The muscle field extends beyond the adminicula, to taper just behind mid-length, and consists of a narrow double adductor ridge, now damaged, and diductors, both marked by weak longitudinal striae. To each side the posterior quarter or so of the floor of the valve is marked by radial ridges and grooves with pits, and shallow dimples lie nearer the cardinal extremities.

Resemblances: The transverse shape, shallow sulcus and fine pitted ornament recall *M. latouchei* DIENER (1911, p. 7, pl. 1, figs. 1—3; pl. 3, fig. 1; WATERHOUSE, 1965, p. 168) from the Anthracolithic of the Shan States. Internal details are not well known for DIENER's species, and further comparison is hindered by the incomplete preservation of the Nepal specimen, though it seems that the interarea might be better developed than in *latouchei*. In length of hinge the specimen comes closer to *M. inflata* WAAGEN of the Upper Productus Limestone.

Genus *SYRINGOTHYRIS* WINCHELL (1863)

Type species: *Syringothyris typa* WINCHELL (1863).

Diagnosis: Hinge at or close to maximum width of shell, ventral interarea very high, subdivided each side of delthyrium into inner vertically striated and outer zone with only horizontal striations. Sulcus and fold with low or no costae, numerous fine plicae to each side, shell punctate. Dental and adminicular plates merge centrally with a hollow or filled syrinx, dorsal plates in *Spirifer*, *Neospirifer*.

Discussion: *Subansiria* SAHNI and SRIVASTAVA (1956) is possibly congeneric, even though its syrinx is apparently more ventrally placed, as emphasized by SAHNI and SRIVASTAVA. Further data on the external ornament would be of value, and possibly provide the basis for at least a a subgeneric distinction from *Syringothyris*. HALL and CLARKE (1894) stated that the shell surface of *Syringothyris* was finely punctate, and resembled "twilled clothe". SAHNI and SRIVASTAVA stated that their material is not punctate. Inspection of the types at the Geological Survey of India, Calcutta, suggested that F 17666 seems to have 6 fine pustules per millimetre, whereas other specimens appear to have either 3 pustules or 6 striae per millimetre

on the surface. Another specimen, F 17671, identified as *Syringothyris* cf. *nagmargensis* BION, has elongated grooves, rather as in *Ingelarella*, and similar ornament is present on Kashmir specimens collected by Dr. G. FUCHS.

Syringothyris lyddekeri? (DIENER, 1899)

Pl. 13, fig. 3

? 1883 *Spirifer striatus* LYDDEKER, pl. 2, fig. 4.
? 1899 *Spirifer lyddekeri* DIENER, p. 72. pl. 3, figs. 1—11.
? 1899 *S.* sp. indet. aff. *lyddekeri* DIENER, p. 74, pl. 5, fig. 2.
? 1915 *Syringothyris lyddekeri* DIENER, p. 38, not pl. 4, figs. 3—6.
? 1928 *S. cuspidata lyddekeri* BION, p. 39, pl. 3, figs. 9—14.
1934 *Spirifer lyddekeri* MERLA, p. 275, pl. 27, fig. 11.
1941 *Syringothyris lyddekeri* MUIR-WOOD, p. 40, pl. 2, fig. 8.

Material: An external mould of a ventral valve from the fine facies of F 105, dubiously related, and a ventral valve and two dorsal valves and broken specimen with valves conjoined, and several other fragments partly exposed in matrix from the coarse facies of F 105.

Lectotype: (Designated by MUIR-WOOD [1941, p. 41].) Specimen figured by DIENER (1899, pl. 3, fig. 7). F 6257, kept at Geological Survey of India, Calcutta.

Diagnosis: Moderately but not extremely transverse, somewhat variable in outline, cardinal extremities obtuse ar early growth stage, acute later, ventral umbo low, little incurved, moderately deep and wide sulcus, and high fold, without costae or median cleft.

Dimensions (in *mm.*):

Width	Length	Height	Umbonal Angle	Sinal Angle	Cardinal Angle	
			Ventral Vave			
58	9.5?	?3.5+		17°	150°	fine matrix
+85	43	+14	?140°	16°		coarse matrix
			Dorsal Valve			
92	?25	?11		?22°	40°	

Description:

External: The specimens are worn and broken, and internal details not exposed. They are transverse in outline, with a low, little incurved ventral umbo from which the posterior walls sweep with backward concavity to the cardinal extremities. These are obtuse for a length of up to 50 *mm.* in the large dorsal valve as in the small external mould of the ventral valve and other small fragments, but the large ventral valve appears to be asymetric, and to have an obtuse cardinal extremity up to 30 *mm.* from the umbo on one side, and an acute angle of 35° to 40° at only 20 *mm.* on the other. The angle appears to remain at about 40° for the full width on this side. From the cardinal extremities the outline curves gently forward to the sulcus and fold, without distinction between lateral and anterior margins. In a small fragment the ventral interarea is 8 *mm.* high and curves through perhaps 35°, with a relatively narrow delthyrium, enclosed by an angle

of 60°. The external mould has a fragment of the interarea attached, lying at right angles to the commissural plane, and marked by high slightly uneven vertical ridges, 2 to 3 per millimetre, bifurcating towards the commissure, and very faint close-set horizontal striae. Little is known of the interarea on the large specimen, except that it is inclined at about 45° postero-ventrally from the commissure, and is gently curved.

The sulcus commences at the umbo, and widens steadily to the anterior margin, where it is possibly produced as a long tongue into the fold of the dorsal valve. In the large specimen the sulcus simply interrupts the otherwise evenly curved profile across the ventral valve and has a concave U-shaped floor. There is no sign of sulcal costae in the worn specimens from the coarse facies, but a very low median costa is seen in the external mould, suggesting that the two may not be conspecific. The dorsal fold is low with a gently convex crest, and steep sides. Ornament consists chiefly of low plicae with well rounded crests and narrow groove-like interspaces. About 6 occur within 5 *mm.* over the umbonal region in the large ventral valve, compared with 3 to 4 anteriorly, and over 40 are present all together. Three to four are present in 5 *mm.* near the mid-line at the anterior margin of the external mould from the fine facies and in this specimen a total of 28 are present, with the outer posterior shell smooth. The interspaces are not so narrow in this specimen, and the innermost pair of plicae lie below the sulcal crest. At least 38 plicae occur on the large dorsal valve, with perhaps a few more laterally, unless the extremities are smooth like those of the external mould. Less than 3 plicae occur in 5 *mm.* next to the fold near the anterior margin, compared with 6 in 5 *mm.* laterally.

Faint traces of concentric growth lines are seen on the large dorsal valve, but the surface of these specimens is too worn to reveal the nature of the fine surface ornament. On the external mould of the specimen from the fine facies, one plication has two or three low longitudinal striae, and the shell is crossed by very slightly lamellose growth lines, about 5 per millimetre near the anterior margin, and 12 per millimetre laterally. The shell is densely pitted (20 per millimetre) but is not clearly punctate.

Internal: A fragment with valves conjoined displays a low dorsal median septum which possibly extends for half of the length of the valve. A leached ventral valve shows a little of the adminicula, wide spaced and short, diverging anteriorly at about 70°.

Resemblances: These specimens agree in general shape and ornament and size with the Ladakh shells described as *S. lyddekeri* by Diener (1899). The types have been examined at Calcutta, and several rubber casts prepared. There are no sulcal costae, the fold and sulcus flare anteriorly, and the innermost pair of plicae lies at the edge or just within the sulcus. Cardinal extremities are obtuse to a width of only 20 *mm.* It should be noted that the ridges each side of the dorsal fold, as shown in Diener (1899, pl. 3, figs. 1, 2, 5—7) are very insigrificant, lower than the median septum, and possibly bordering the muscle field. They are a little more prominent in the specimen shown in Fig. 10. The dorsal valve has wide crural plates converging inwards dorsally at a very high angle each side of a moderately large cardinal process, and a low median septum extending to about mid-length. The specimen of fig. 2 (F 6252) has slightly coarser costae and less conspicuous muscle

scars than the others, and whereas the muscle scars occupy over half of the length of the valve in fig. 1, they are only about a third of the length in fig. 5. A mould of a ventral valve next to the dorsal valve of fig. 7 shows the syrinx typical of the genus. About 5 pits per millimetre were counted on a ventral mould of a ventral valve, more or less in rows, but none can be seen on the latex casts.

The specimen figured by DAVIDSON (1866, pl. 1, fig. 5) (not fig. 4 as stated by DIENER, 1899, and BRANSON, 1948), as *Spirifer* sp. indet., was referred to *S. lydekkeri* by DIENER but has a median costa even more prominent than that of the fine facies of F 105.

The specimen figured in DIENER (1899, pl. 5, fig. 2) as *S.* aff. *lyddekeri* would appear to be too elongated with unusually obtuse cardinal extremities to be placed in *lyddekeri*, as noted by MUIR-WOOD (1941), but, coming from the same horizon as typical *lyddekeri* probably represents an unusual variant of the species. The specimen of DIENER (1899, pl. 3, fig. 5) is more or less comparable.

Examination at Calcutta of the specimens referred to *Syringothyris lyddekeri* from the Fenestella Shales by DIENER (1915, p. 38, pl. 4, figs. 3—6) suggested they have 6 punctae per millimetre.

The Upper Agglomeratic specimens referred to *Syringothyris cuspidata lyddekeri* by BION (1928, p. 39, pl. 3, figs. 9—14) are rather variable in outline but include shells that are more transverse than those of DIENER's lot, and appear to have slightly coarser plicae and a wider sulcus with an angle near 30°. The curvature of the interarea cannot be ascertained from figures though fig. 14 suggests it is concave.

BION (1928) referred *Spirifer curzoni* DIENER (1903, pl. 7, figs. 2—6) to *S. lyddekeri*. The Anthracolithic specimens have a higher more triangular ventral valve, almost flat interarea, sulcal angle of 40° and possibly finer ribs, though I noted at Calcutta that the two seemed close, apart from a possibly wider and lower dorsal fold. As noted below, internal differences between the two are considerable. DIENER (1903) considered the two to be distinguished by the strong concentric lamellae of *lyddekeri*.

The Yunnan specimen compared to *Spirifer lyddekeri* by REED (1927, pl. 13, fig. 10) has more outwardly curved costae, and is so incomplete that identification must remain unreliable. The Laotian specimen of MANSUY (1912 b, pl. 8, fig. 9) is more elongated than DIENER's types. The Upper Permian specimen from the Karakorum, described by MERLA (1934) agrees well with a small specimen represented from DIENER's original lot (with pl. 6, fig. 3), even having a similar pointed umbo, and fine lateral ribs, though it perhaps is a little more transverse than usual. Another Upper Permian specimen figured by MUIR-WOOD (1941) from the Lachi Series is too poorly preserved to be assessed with accuracy. An incomplete dorsal valve was figured from the Kuling Series as *Spirifer striatus* by LYDDEKER (1883, pl. 2, fig. 4), according to MUIR-WOOD (1941, p. 41). However none of the Permian occurrences of Nepal, Kashmir, Karakorum or Sikkim can be considered as firmly established as identification has been based on few, sometimes poorly preserved specimens, of which not one shows internal detail.

Stratigraphic position of *S. lyddekeri*.

MUIR-WOOD (1941, pp. 41, 42) apparently accepted DIENER's statement of 1899 that the types of *S. lyddekeri* came from the Zewan or Barus beds north of Eishmakam, as well as from quartz sandstone of uncertain age from the Laddakh Valley. However DIENER (1903) and MIDDLEMISS (1909, p. 319, 1910) later discovered that the locality north of Eishmakam underlay the Upper Permian beds. Rubber moulds which I prepared at Calcutta from specimens from both localities show that the characteristic Lower Permian „*Camarophoria*" *dowhatensis* DIENER (1915) of the Fenestella beds is also present, as confirmed by further collections from the region by Dr. G. FUCHS. The apparent presence of *S. lyddekeri* high in the Permian is anomalous, but as noted above, is not well founded and calls for further enquiry.

Genus *PUNCTOSPIRIFER* NORTH (1920)

Type species: *Punctospirifer scabricosta* NORTH (1920).

Diagnosis: Transverse plicate punctate Spiriferinids, broad sulcus and fold without costae, and ornament of close-set concentric wrinkles and radial striae. Ventral valve with dental and adminicular plates and high median septum, dorsal valve with crural plates, socket plates, spiralia, possibly without jugum. (See CAMPBELL, 1959 b.)

Punctospirifer sp.

Pl. 13, fig. 6

Material: A broken dorsal valve from F 108.

Diagnosis: Moderately large transverse specimen with high fold flaring anteriorly, and well rounded plicae, curving outwards.

Dimensions (in *mm.*):

Width	Length	Height	Septum	Umbonal Angle
34	18.5	8	11	150°

Description: The specimen is moderately large, with a low umbo, damaged cardinal extremities, a moderately high fold with rounded crest, flaring considerably near the anterior margin, and at least four pairs of plicae which curve laterally outwards—one or two pairs were possibly present at the cardinal extremities now destroyed. Fine surface ornament consists of concentric growth wrinkles, 2 or 3 per millimetre, and what appear to be fine short radial filae—7 to 8 per millimetre, though it must be emphasized that the poorness of preservation prevents certain determination of the detail. A long median septum is present.

Resemblances: This specimen appears to belong to *Punctospirifer* from its external ornament and flaring fold. The Zewan specimens compared to *Spirifer kentuckensis* SHUMARD by DIENER (1899, pl. 5, figs. 11, 12) have strong concentrics but are distinguished by alate extremities. The Chitichun specimens identified as *Spiriferina cristata octoplicata* SOWERBY by DIENER (1897 a, p. 39, pl. 7, figs. 5—7) are closer, with a flaring fold, outwardly curved plicae, and low umbo, though they are a little smaller and seem to

have a longer hinge. The Salt Range specimens so identified by WAAGEN (1883, pl. 49, figs. 3—7) have a long hinge and straight plicae, whereas the Upper Productus shells referred by WAAGEN (1883, pl. 49, figs. 8, 9) to *Spiriferina multiplicata* SOWERBY are a little closer in these respects, though more elongate. The Zewan specimen identified with *S. cristata fascigata* by DIENER (1915, pl. 9, figs. 9 a—d) is moderately similar in shape but the fold does not appear to flare so much, and the plicae seem to be straighter.

Genus *CLEIOTHYRIDINA* BUCKMAN (1906)

Type species: *Athyris royssii* DAVIDSON (1862), not LÉVEILLÉ (1835).

Diagnosis: Subcircular or oval biconvex shells with foramen, ventral sulcus and dorsal fold in some species, ornament of fimbriate growth-lamellae fringed anteriorly by spines. Teeth supported by short dental lamellae. Dorsal hinge plate perforated, adjoined by dental sockets, spiralia laterally directed, jugum complex, described by DUNBAR and CONDRA (1932) as saddle shaped, with a median process passing back to subdivide into two lamellae which recurve dorsally parallel to the bases of the primary lamellae.

Cleiothyridina subexpansa (WAAGEN, 1883)

Pl. 8, fig. 3; Pl. 10, fig. 3

1883 *Athyris subexpansa* WAAGEN, p. 478, pl. 39, figs. 1—5.
1897a *A. subexpansa* DIENER, p. 61, pl. 10, fig. 4.
cf. 1899 *Athyris* cf. *expansa* not PHILLIPS, DIENER, p. 58, pl. 6, figs. 11 a, b.
? 1915 *Spirigera subexpansa* DIENER, p. 94, pl. 10, fig. 4.
? 1944 *Athyris (Cleiothyridina) gerardi* not DIENER, REED, p. 260, pl. 36, figs. 4, 5.

Material: A dorsal valve, partly leached by nature from F 108, and a natural internal mould of the ventral valve, with some of the external ornament, from F 112.

Lectotype: (Here designated.) Specimen figured by WAAGEN (1883, pl. 39, fig. 4). F 3458, kept at Geological Survey of India, Calcutta.

Diagnosis: Transverse little inflated shells with shallow anterior ventral sulcus, concave posterior walls, and 15 to 20 spines in 5 *mm.*

Dimensions (in *mm.*):

Collection Number	Width	Height	Length	Umbonal Angle	Cardinal Angle
108	36	21.5	8.5	127°	140°
112	21	16	5		?130°

Description:

External: The specimens are little inflated, and transversely oval in outline with not very prominent nor incurved umbones, rounded cardinal extremities, the posterior walls concave in outline and the maximum width placed near the anterior third of the shell length. A shallow sulcus of moderate width commences over the anterior half of the ventral valve, though there does not appear to be a corresponding fold on the dorsal valve. A few strong concentric growth-wrinkles cross the valves over their anterior halves,

and curtains of spines arise from concentric lamellae, about 17 occurring along 5 *mm.* near the anterior margin of the ventral valve, with slightly swollen bases. Their length and radial spacing are not known.

Internal: The teeth are supported by plates which diverge anteriorly at about 60° and pass almost vertically to the floor of the valve, though in fact they are rather concave inwards. Between the plates the floor of the valve is somewhat damaged, and the umbo lost, and in front of the anterior termination of the plates, within the sulcus, is a median groove, extending just past the anterior third of the shell length, and joined posteriorly by two low ridges, converging anteriorly at about 45°. The floor of the valve is also traversed by other low radial ridges, two especially prominent in front of the dental plates, and seemingly marked by shallow pits, about 8 per millimetre in close-set rows, unless the pits are due to the grain of the matrix.

Little of the cardinalia are visible in the dorsal valve, apart from the base of socket plates, and a low median septum extending over the posterior fourth of the shell length. Short radially elongated ridges lie over the posterior floor.

The shell is about 0.5 *mm.* thick.

Resemblances: Few significant details of dimensions for the spines, foramen, and interior details are available for the specimens from Nepal, so that we must fall back on mere shape. Rather too many species seem to have been described from the Salt Range by WAAGEN and REED but one of the most distinctive is *C. subexpansa,* characterised by a transverse oval outline, low umbo, and shallow sulcus. The type (pl. 39, fig. 4) is cracked a little on the right side of the ventral valve and exposes the ventral plates a little and the anterior is damaged, but it still represents a nicely preserved specimen. F 3457 has about 3 to 4 spines per millimetre.

It should be noted that the specimen shown in fig. 5 is inaccurately figured and the aspect presented in fig. 5 b now largely destroyed. The ventral foramen faces dorsally in the type. The Chitichun specimen of DIENER (1897 a) is very close, with a very shallow sulcus, and the Zewan specimens (DIENER, 1915, p. 94, pl. 10, fig. 4) have a longer sulcus arising at the ventral umbo and the posterior walls are much less concave in outline, though DIENER noted that one of the four specimens has a shallow sulcus. The Chitral specimen described by REED (1925, p. 53, p. 89, pl. 7, fig. 4) is close in general appearance, but details of spines and foramen are not described, REED noting that the specimens are poorly preserved. The Zewan specimen described by DIENER (1899, pl. 6, figs. 11 a, b) as *Athyris* of *expansa* is close and could be identical, but has been much idealised in the figure to judge from inspection of the specimen. It seems to lack a sulcus. The somewhat similar specimens from much the same horizon that were described as *Athyris capillata* by WAAGEN (1883, pl. 39, figs. 6—9; pl. 40, figs. 1—5; pl. 42, fig. 15) have a similar spine density, but are apparently distinguished by a deeper sulcus anteriorly, and a more arched dorsal valve (F 3460—3463). Also a shallow sulcus is present in the dorsal fold (pl. 40, fig. 1).

The Chitral specimen referred by REED (1925, pp. 53, 89, pl. 7, fig. 4) to WAAGEN's species is moderately close in outline, but is likely to be part

of the suite of *Cleiothyridina* from the same locality that were named *Athyris ailakensis* by REED. This species is somewhat variable in shape, but is generally characterised by a sulcus in each valve, and by an extended ventral umbo.

The Maokou specimens described as *Athyris* aff. *subexpansa* by ZHANG and LI (1962, pl. 4, figs. 1—6) are more elongated and globular than WAAGEN's types. Nor is there more than moderate similarity to the Arctic specimen compared with *C. subexpansa* by HARKER and THORSTEINSSON (1960, p. 73, pl. 24, figs. 1, 2). Spines appear to be fewer and coarser on this specimen than in the Nepal shells.

The Kuling specimens named *A. gerardi* by DIENER (1899, pl. 6, figs. 12, 14) are very badly preserved, with no surface left, nor reliable part of the posterior plates. A small foramen is present. They are somewhat longer than *subexpansa*, with straighter posterior walls and a long shallow sulcus according to the figures, but could be close. A Kiunglung specimen of DIENER (1897 b, pl. 5, fig. 5) named *A. royssii*, later synonymised by DIENER (1899, p. 59), is of much the same shape. Specimens later recorded as *Athyris gerardi* from the Productus Shales of the Lissar Valley (1903, pl. 5, figs. 10, 11) are moderately similar in the outline of the posterior walls, whereas one of the specimens named *Spirigera gerardi* by DIENER in the same work (1899, pl. 9, figs. 6, 7) has concave posterior walls.

The Laos specimen of MANSUY (1913 a, pl. 9, figs. 7 a, b) is much narrower and the Maping Limestone specimen of GRABAU (1936, pl. 26, figs. 4 a, b) seemingly lacks a sulcus, and though its posterior walls are less concave in outline, is not unlike *subexpansa*. Such resemblance may be only superficial, many of the details of GRABAU's specimen being undescribed.

ČERNYŠEV's (1902, pl. 43, figs. 1—3) specimens of *gerardi* are less extended posteriorly and more rounded in front of the hinge.

The Upper Productus Limestone specimens referred by REED (1944, pl. 36, figs. 4, 5) to *gerardi* also seem to be closely allied and perhaps identical with *subexpansa* in shape, including moderately concave posterior walls, though there is no visible sulcus in the figures except for a shallow anterior in fig. 5.

The Upper Productus specimens named *C. accola* REED (1944, pl. 37, figs. 1, 2) are moderately similar, especially fig. 2.—fig. 1 having the ventral umbo more extended posteriorly. In fig. 2 b, the specimen is shown narrower than it really is. The form recalls *C. capillata* in its low umbo and sulcate retraction of growth-lines (without forming a depression in the transverse profile) in the dorsal valve—like F 3465 of WAAGEN and REED's *gerardi* (REED, 1944, p. 261). But there are only 2 spines per millimetre, and growth lamellae are more spaced posteriorly and the sulcus seems a little wider.

Genus *HOSKINGIA* CAMPBELL (1965)

Type species: *Dielasma trigonopse* HOSKING (1933).

Diagnosis: Moderately large species with sulcus in both valves, and convex umbonal regions, dental plates, outer hinge plates, and inner hinge plates forming a sessile septalium, crural bases well developed, points high,

loop terebratuloid, but without the transverse band, punctae 100 to 180 per square millimetre.

Discussion: This genus is close in most respects to *Beecheria* HALL and CLARKE, and the limits of the two genera are poorly defined, though it is possible that punctation is consistently less dense in *Hoskingia*. The Nepal form appears to be allied to *Hoskingia* but has slightly different muscle scars, the adductors being narrower and the diductors longer and pedicle adjustor scars more subrectangular.

?Hoskingia latouchei (DIENER, 1903)

Pl. 14, fig. 1

1897b *Dielasma* sp. indet. DIENER, p. 48, pl. 3, fig. 5.
1903 *Dielasma La Touchei* DIENER, pp. 111, 192, pl. 5, figs. 7—9.
1915 *Dielasma La Touchei* DIENER, p. 97, pl. 10, figs. 13—14.

Material: A natural internal mould of a specimen from F 105 with the dorsal valve largely destroyed.

Holotype: (By original designation.) Specimen figured by DIENER (1903, pl. 5, figs. 7 a—d). Kept at Geological Survey of India, Calcutta.

Diagnosis: Large little inflated shell, a little less subtriangular than *latouchei* types, with median convexity posteriorly on ventral valve, replaced by sulcus in front. About 140 punctae per square millimetre. Foramen small.

Dimensions (in *mm.*):

Width	Length	Height	Dental plate Length	Dental plate Apart	Umbonal Angle	Cardinal Angle	Sinal Angle	Hinge Width
26	42	6	8	4	65°	120°	30°	9.5

Description:

External: The specimen is of an elongated oval shape, and little inflated, but not apparently flattened. The tip of the ventral umbo is occupied by a tiny foramen less than 1 *mm.* in diameter, which slopes at 110° from the anterior surface, facing posteriorly at about 80° from the commissure. The dorsal umbo is low and the posterior part of the dorsal valve little inflated. The posterior walls are low and almost straight in outline, diverging at 65° from the umbo to the rounded cardinal extremities, and the outline then curving forward to the maximum width of the shell, placed at about 0.75 of the length, behind a broad anterior margin. The sulcus occupies much of the anterior half of the shell, but is replaced posteriorly by a convexity over the muscle area. Walls of the sulcus are steep, and the floor broad and gently concave. On one side of the sulcus there seems to be a narrow plication bordering the sulcus, on the other, none.

Internal: Internal details are well displayed on the ventral valve. The dental plates are short, and placed close to the posterior walls, converging to the floor of the valve at about 60°. Between them is a large and long muscle field, depressed as much as 1.6 *mm.* below the floor of the valve and extending almost to mid-length, with sides diverging anteriorly for 20°, and covered by fine longitudinal striae (7 to 9 per millimetre). The posterior

part between the dental plates is a little less depressed, and is subdivided medianly by two narrow longitudinal grooves, and bordered by grooves with a median ridge down the centre. At the anterior end of the dental plates the muscle field widens a little and deepens abruptly, with a lobate posterior margin, and fairly smooth in front, apart from fine growth striae parallel to the anterior margins and a wide shallow groove on one side. The median ridge is replaced anteriorly by a short median groove, and the adductors, between the two median grooves, form a short broad ridge to each side, extending for less than a third of the length of the field. To each side the inner or true diductors are depressed below the outer diductors, or pedicle adjustor scars, and the depression continues forward beyond the anterior edge of the muscle field to the anterior margin of the shell. There would seem to be about 12 pits per millimetre, but the number is hard to ascertain because of the coarseness of the matrix.

A small laminated cardinal process lies under the dorsal umbo. The umbonal region of the dorsal valve has been crushed and is not easy to interpret. The sockets seem to be crenulated by both moderately coarse (3 per millimetre) and much finer striae parallel to their anterior margins. A sessile septalium is suggested by growth wrinkles over the posterior floor, and would seem to have been both pressed against the floor of the valve, and mashed laterally to break and form a high median ridge. Alternatively there might indeed be a high median septum, no septalium, and crura stemming from the socket plates, as in *Pseudodielasma* BRILL.

Resemblances: The swollen median posterior part of the valve and anterior sulcus typify *Dielasma latouchei* DIENER from the Productus Shales of Lissar Valley and Zewan beds of Kashmir. DIENER (1903) stated that the foramen was large, but the one figured in DIENER (1903, pl. 5, fig. 7 a) is not particularly big. His specimens tend to be more triangular in outline, except for the small specimen figured as *Dielasma* sp. Perhaps this difference is partly to be explained by the small size of the Nepal specimen, but growth-lines on DIENER's large specimens do not appear to show much change in shape with increase in size.

Carboniferous

Genus *RHIPIDOMELLA* OEHLERT (1890)

Type species: *Terebratula michelini* L'EVEILLÉ (1835).

Diagnosis: Subcircular or oval shells, dorsal valve convex, ventral valve convex or convexo-concave, hinge short, ornament of ribs and spines, shell punctate. Ventral adductors narrow, surrounded by large flabellate diductors, dorsal sockets enclosed by short strong crural plates each side of sturdy cardinal process, broad to narrow septum, adductors in two pairs.

Discussion: The Nepal specimens are unusually large and transverse for *Rhipidomella*, but appear to belong to this genus from general shape, ornament, and dorsal adductors, which form two subquadrate pairs much

as figured by DAVIDSON (1861, pl. 30, fig. 10) for *R. michelini*. Only the anterior pair is prominent in a figure by DEMANET (1934, pl. 2, fig. 6 a), and CAMPBELL (1957, p. 51) considered that one pair was developed in Lower Carboniferous forms such as *Rhipidomella australis* (MCCOY, 1847) (and see especially *Rhipidomella fortimuscula* (CVANCARA, 1958, pl. 109, figs. 9, 10) in contrast to two pairs in Upper Carboniferous and Permian forms. It seems difficult to accept this hypothesis since pre-Carboniferous form ascribed to *Rhipidomella* by SCHUCHERT and COOPER (1932) appear to have two pairs of dorsal adductors, and some Permian forms such as *R. cora* d'ORBIGNY (see KOZLOWSKI, 1914; CHRONIC in NEWELL *et al* (1953) have a very faint posterior pair. Perhaps more than one genus is involved.

Rhipidomella sp.

Pl. 14, figs. 2, 3, 5, 6; Pl. 15, figs. 4, 6

Material: Two dorsal valves and two specimens with valves conjoined from F 127. Three have been leached in acid, but the internal moulds of the specimens with valves conjoined proved to be highly calcareous, and were largely destroyed.

Diagnosis: Large transverse little inflated biconvex shells with shallow sulcus in each valve, up to 15 costae in 5 *mm.* anteriorly, spines emerge abruptly from shell, two pairs of moderately impressed dorsal adductors.

Dimensions (in *mm.*):

Width	Length	Height	Umbonal Angle	Costellae in 5 *mm.* Posteriorly	Anteriorly
			Ventral		
41	?34	8.5	130°	11	9
			Dorsal		
33	28	3.5	135°	12	8

Description:

External: The specimens are little inflated and transverse, with the margins somewhat broken, and vaguely defined to the extent that the dorsal valve is possibly rather wider than it first appears. The ventral valve is more inflated than the dorsal, with an inconspicuous umbo, and a weakly concave interarea 3.5 *mm.* high, diverging anteriorly each side of the umbo, and bulging outwards medianly in a triangular convexity that widens towards the commissure. The dorsal umbo protrudes a little more posteriorly, but no interarea is visible. The hinge seems to be a little less than half of the width of the shell and the cardinal extremities highly obtuse at 150° to 160°. No ears are differentiated, though the lateral extremities are a little flattened on both valves, especially the dorsal, even becoming concave on one large specimen. A shallow median sulcus with an angle of 15° arises over the posterior third of the ventral valve, and fades in prominence anteriorly, and an even shallower sulcus appears on the dorsal valve near mid-length, and persists to the anterior margin, which is slightly recessed. Costellae have rounded crests and steep sides, and interspaces of inverse profile. Growth

lamellae are low but sharply defined on the decorticated ventral valve, with a somewhat zig-zag pattern, arching anteriorly over the costellae. On the leached internal mould of the dorsal valve the costellae become finer anteriorly, increasing from 7 in 5 *mm.* near mid-length to 11 near the anterior margin. Increase is by intercalation. Interspaces are finely pitted (15 to 20 per millimetre), but size and spacing of the pits vary considerably. A few spines are seen anteriorly on the decorticated ventral valve, the costellae dilating somewhat and the spine base occupying most of the width of the costella, but not prolonged posteriorly. On the leached external moulds there are about 15 costellae in 5 *mm.* near the anterior margin, crossed by irregularly spaced short growth lamellae which do not arch, and lie 0.2 to 0.5 *mm.* apart. On the dorsal valve about 5 costellae occur in 1 *mm.* near the umbo, and about 3 in 1 *mm.* near the anterior margin, and growth lamellae are as prominent as on the ventral valve. The most arresting feature of the moulds are the spine-bases. Two sets are present. Large spine bases up to 0.5 *mm.* long and perhaps 0.2 to 0.3 *mm.* wide lie more or less in quincunx over the valves, about 1 *mm.* apart, and entering the shell at a low angle close to 15° under the costellae. There is also a dense pattern of finer tubules, over the entire shell, less regularly arranged, about 15 occuring in 1 *mm.*, these presumably passing into the pits seen externally.

Internal: Details of the ventral valve are not known. In the dorsal valve, the dental sockets are enclosed between short outwardly curved thick crural plates. In between lies a stubby cardinal process with a round crested anterior face that is marked by a shallow median incision which passes forward into a short median ridge. This ridge lies on a large broad median septum which tapers anteriorly, extending no further than the posterior third of the shell length. To each side is a deeply impressed adductor complex, comprising a posterior wide subtriangular subdivision with one or two grooves, and a larger, longer more or less subquadrate anterior sudivision, the two separated by a low ridge. Low mounds and dimples cover the posterior floor to each side, and the external ornament is visible anteriorly.

In the leached specimen with valves conjoined the dorsal shell is 2.5 *mm.* thick at mid-length.

Resemblances: The specimen are characterised by their low inflation and transverse outline. A specimen from Baroghil Ailak assigned by REED (1925, pl. 7, fig. 13) to *Schizophoria* aff. *juresanensis* ČERNYŠEV is less transverse and has a prominent ventral umbo. A Kashmir *Schizophoria* from the Syringothyris Limestone figured by DIENER (1915, pl. 1, figs. 10 a—d) is much more inflated, more elongated and again has a more prominent ventral umbo. Lower Carboniferous specimens from Yunnan referred by REED (1927, pl. 8, figs. 3, 4) to *Orthis (Rhipidomella) michelini* are of comparable size, but are more elongated and have slightly more prominent umbones, and broad little inflated cardinal extremities. REED stated that the ventral valve is a little more convex than the dorsal, that about 10 costae occur in 5 *mm.*, and that concentric ornament is not visible.

R. michelini also reaches a similar large size in Europe (cf. PAECKELMANN, 1930, pl. 10, fig. 1) but is usually more elongated. The Nang-po *S. resupinata* of MANSUY (1913 b, pl. 4, fig. 16) is also more elongated with fine costellae.

On the other hand *R. ostrogensis* Besnossova in Saryčeva *et al* (1963, p. 75, pl. 3, figs. 1—4) is similarly transverse and sulcate, but is even larger, and appears to have slightly coarser costellae with narrower interspaces.

Orthotetid gen. and sp. indet.

Description: A fragment of external ornament from F 127. The posterior part of the specimen is concave, and the anterior part convex, to judge from the way the ornament is most emphasized. The outline of the specimen is obscured by matrix and breakage, but would seem from growth-lines to have probably been subtriangular, with a narrow hinge and maximum width near the anterior third of the shell length. About 18 costellae occur in 5 *mm.* postero-laterally, compared with 9 in 5 *mm.* in the middle of the shell, anteriorly. Increase is by intercalation. Crests are rounded, with interspaces evenly concave and of similar width. No spines are visible. The entire shell is crossed by concentric wrinkles with crests just over 1 *mm.* apart anteriorly, the costellae being highest at the wrinkles, and losing height in the interspaces. The anterior edge of the wrinkles is a little steeper than the posterior edge. There are faint signs of pores, at about 15 to 20 per millimetre.

Genus *EOMARGINIFERA* Muir-Wood (1930)

Type species: *Productus longispinus* Sowerby (1814).

?Eomarginifera sp.

Pl. 14, fig. 4; Pl. 15, fig. 2

Material: A distorted ventral valve from F 111, with the shell removed from the anterior half.

Diagnosis: Transverse shells with radial ribs, posterior concentric rugae.

Dimensions (in *mm.*):

Width	Length	Height
41	19	13

Description: The specimen is transverse, and has been squeezed to exaggerate the height and width, but was probably slightly transverse, with a suboval outline, slightly obtuse cardinal extremities and moderately steep posterior walls which diverge anteriorly at 140°. Hinge and umbo are poorly preserved. Over the posterior part the shell is medianly flattened, and in front, the internal mould is broadly and gently sulcate. Low wrinkles with crests just over 1 *mm.* apart cover the posterior third of the valve. Otherwise the posterior surface of the posterior shell is too worn to show much of the ornament apart from traces, but the inner mould in front is marked by strong costae, up to 5 occurring in 5 *mm.* each side of the sulcus, and becoming finer laterally, and very low anteriorly on the internal mould. Details of spines and interior are not known.

Resemblances: In some respects this specimen compares with a specimen from the Syringothyris Limestone near Ainu referred by Diener

(1915, p. 5, pl. 1, figs. 2 a—c) to *Productus longispinus* SOWERBY, the Kashmir specimen being smaller, but more or less comparable in costae, posterior wrinkles, sulcus and shape. DIENER warned that the ornament was fine in his specimens, and that they might belong to *P. cora*, but seemed more confident of an affinity to *longispinus* for specimens from Lipak, stating that the ornament was stronger than that of *cora* (1915, p. 124, pl. 11, fig. 13). Zewan specimens compared to this species by DIENER (1899, p. 26, pl. 1, fig. 11) are more transverse, with large ears and very low concentric ornament, and are unlikely to be congeneric. Compared with *Productus longispinus*, as figured in SOWERBY (1814, pl. 68, fig. 1); DAVIDSON (1861, pl. 35, figs. 5—17); MUIR-WOOD (1928, pl. 11, figs. 1—4) and MUIR-WOOD and COOPER (1960, pl. 61, figs. 1—17) the costae are a little coarser in the Nepal form, but there could be, as far as is known, possible agreement at generic level. However the poor preservation, and availability of only one ventral valve renders even this uncertain.

Lower Carboniferous specimens referred to *longispinus* from Shantung by FRECH (1911, pl. 12, figs. 1 a—e) are distinguished from the European types by their larger ears, recalling Russian specimens figured by SARYČEVA and SOKOLSKAJA (1952, pl. 45, fig. 231). Ta-shih-wo specimens of REED (1927, pl. 9, figs. 5, 7) are transverse like the Nepal specimen, but have more concentric wrinkles.

Genus *LINOPRODUCTUS* CHAO (1927)

Type species: *Productus cora* d'ORBIGNY (1842).

Diagnosis: Concavo-convex Linoproductidae with geniculate trail, distinguished from allied forms chiefly by ornament of radial costellae, increasing by intercalation, crossed by low wrinkles restricted to flanks on ventral valve, covering disc of dorsal valve, which has repeated trails and diaphragms, or concentric lamellae externally. Spines rare on dorsal valve, in row along hinge on ears and arising from costellae over ventral valve. Ventral adductors considered by MUIR-WOOD and COOPER to be non-dendritic in distinction to those of *Ovatia*.

Discussion: MUIR-WOOD and COOPER (1960) imply that *Linoproductus* is chiefly Upper Carboniferous and Permian in age, and tends to be transverse in contrast to the elongate genus Lower Carboniferous genus *Ovatia*. The Nepal and related Kashmir specimens appear to be exceptional in these regards, being elongated, and apparently Lower Carboniferous in age, but with musculature and dorsal ornament as in *Linoproductus*.

A Lower Carboniferous member of the Linoproductinae which has apparently similar ventral muscle scars is *Balakhonia* SARYČEVA (1963), but species of this genus have less conspicuous wrinkles on the dorsal exterior, and appear to have finer spines on the ventral valve, whereas a rare ventral spine on the new form is as large as in *L. cora* (cf. KOZLOWSKI, 1914; CHRONIC in NEWELL *et al*, 1953; MUIR-WOOD and COOPER, 1960). Also the fine radial filae seen on both valves of the new species are missing from *B. kokdscharensis* (SARYČEVA, 1963, pl. 38, fig. 8 b), though they have not been reported in *Linoproductus* either, suggesting the possibility that the species is of new

generic rank. In form, *Balakhonia* is reminiscent of *Striatifera* rather than *Linoproductus*.

Linoproductus pollex n. sp.

Pl. 15, figs. 3, 5

1903 *Productus lineatus* (not WAAGEN) DIENER, p. 138, pl. 7, fig. 1.
1915 *Productus cora* (not d'ORBIGNY) DIENER, p. 3, pl. 1, fig. 1; pl. 11, fig. 33.
1965 *Productus cora* SARKAR, p. 94, figs. 1 a, 2 a.

Material: A specimen with valves conjoined, from F 67, leached in acid.

Holotype: Specimen figured in pl. 15, figs. 3, 5, from F 67.

Diagnosis: Elongate shell with extremely incurved ventral umbo, long steep massive umbonal shoulders, shallow median sulcus, coarse costellae with fine radial filae, rare large spines.

Dimensions (in *mm.*):

Ventral Valve				
			Adductors	
Width	Length	Height	Width	Length
34	50	15.5	4.7	7.5

Description:

External: The specimen is elongated with a strongly incurved umbo and overturned posterior walls which diverge anteriorly at 120°. Ears are small, and the maximum width apparently placed well in front of the hinge. A shallow median sulcus and corresponding dorsal fold arise close to the umbo, but do not widen much over the anterior half, and fade before reaching the anterior margin. There is no obvious change in curvature between visceral disc and the very thin trail. Four or five low wrinkles lie to each side of the umbo on the ventral valve, but fail to cross the visceral disc, and about 12 low wrinkles cross the disc of the dorsal valve, but none are present on the trail. Costae cover the valves, about 6 occurring in 5 *mm.* on the ventral valve at about 7 *mm.* from the umbo, compared with 7 in 5 *mm.* over the anterior shell. Crests are rounded, and interspaces of similar width, and evenly concave. Many are now bifurcate posteriorly, possibly due to decortication. The shell surface is also covered by fine radial capillae, about 7 to 8 per millimetre. Ventral spines leave no trace except for one large one 1.2 *mm.* wide and 2 *mm.* long on the side of the sulcus, and so are presumably few. There seems to be no spines over the dorsal valve, apart from the posterior walls and ears, which cannot be seen.

Internal: The adductor platform is subquadrate, subdivided by a median groove which contains a median ridge, and relatively smooth apart from very fine more or less longitudinal striae. To each side the diductor impressions are heavily scored by anastomosing ridges and very narrow grooves (about 3 in 2 *mm.*). The anterior margin of the diductors is ill-defined, the grooves and ridges continuing into an anastomosing and pitted complex marked by short fine striae and covering the posterior third of the shell. This complex passes forward into slightly elongated pustules. Immediately in front of the adductors the floor of the valve is densely pustuled, without ridges for about 5 *mm.*

Resemblances: Of specimens from the same general region, the closest are described from the Syringothyris limestone of Kashmir and Lipak by DIENER (1915, p. 3, pl. 1, fig. 1; pl. 11, fig. 33) as *Productus cora* d'ORBIGNY. They have steep posterior and lateral walls and low wrinkles laterally, though the costae seem to be finer, at 8 or 9 in 5 *mm.* to judge from the figure. SARKAR (1965) has recently demonstrated the extremely incurved nature of the ventral umbo. Another moderately comparable specimen is figured as *P. lineatus* from the lower division of the Spiti Anthracolithic by DIENER (1903, pl. 7, fig. 1), with incurved umbo and steep posterior walls, and flattened non-sulcate venter. Specimens referred to *P. cora* by DIENER (1911, pl. 3, figs. 3—13) from the Anthracolithic of the Shan States have costae of similar density to those of the Kashmir shell, but are more transverse, with large ears and many wrinkles. Baroghil Ailak specimens ascribed to *Productus cora lineatus* WAAGEN by REED have slightly coarser ribs, more narrowly diverging posterior walls, and a more rounded venter. They are rather similar in shape to the *P. cora* shells described by ČERNYŠEV (1902), but lack the transverse growth-lines of the Russian specimens. Upper Productus Limestone specimens of *L. lineatus* (WAAGEN) which I collected from Narmia and Chhiddru are certainly close, but appear to have slightly finer ornament, slightly more rounded posterior walls, and to lack a sulcus of any depth.

As figured by MUIR-WOOD and COOPER (1960, pl. 111, figs. 3—6) *L. cora* (d'ORBIGNY) is close in incurved umbo and steep posterior walls and lateral wrinkles, but like many other species, has a slightly more rounded venter and finer more sinuous radial ornament. *L. platyumbonatus* DUNBAR and CONDRA (1932, pl. 31, figs. 1—5) from the Pennsylvanian of Missouri and Kansas is rather similar to the Nepal and Kashmir shells in ornament, profile and presence of a sulcus on at least some specimens, but there is no indication on the Nepal specimen of the anterior funneled trail and convergent ornament.

Tournaisian specimens recorded from the Lower Burindi Group of New South Wales by CAMPBELL (1956, p. 479, pl. 49, figs. 11—13) as *Linoproductus* sp. have no sulcus and finer ornament and more persistent wrinkles on the ventral valve. But unlike most other species the Australian shells have a somewhat comparable ventral umbo and fairly widely diverging posterior walls. Internal details are obscured on the Australian ventral valves. Another perhaps closer form, described as *L. niigaensis* ČERNYAK in DEDOK and ČERNYAK (1960, p. 55, pl. 2, figs. 1—4) from the C_1^d beds of Taimyr Peninsula has slightly finer costellae and more flaring margins, but is closely similar in overall shape, with massive umbonal shoulders.

Productus yunnanensis LOCZY (1890, 1897) as figured by REED (1927, pl. 8, figs. 1 a—d; pl. 9, figs. 1 a—b) from the type locality in the Lower Carboniferous of Ta-shih-wo, Yunnan, has a narrow attentuated umbo and large ears and strong concentric growth-lamellae. REED's specimens were referred to *Balakhonia* by SARYČEVA (1963). The Malayan shell figured as this species by MUIR-WOOD (1948, p. 34, pl. 3, figs. 5 a—b) is very elongated with costellae of similar density, but still lacks such widely diverging posterior walls.

A closer form is the Visean shell of Yunnan and Kansu, referred by CHAO (1927, p. 135, pl. 14, figs. 5 a—c, 9—12) to *L. tenuistriatus* (VERNEUIL,

1845, p. 260, pl. 16, fig. 6), but these specimens and others figured under the same name by ČERNYŠEV (1902, pl. 36, figs. 4, 5; pl. 55, fig. 6), DIENER (1911, pl. 4, figs. 1, 2), SARYČEVA and SOKOLSKAJA (1952, pl. 20, fig. 141) and others all have less widely diverging, more rounded posterior shoulders on the ventral valve, and finer costellae. DIENER (1915, p. 4) also commented on the similarity, and stated that his Kashmir species have more regular ornament. The Malayan shells described by MUIR-WOOD (1948, pl. 3, figs. 1 a, b, 2; pl. 5, fig. 3) differ in the same way, but do have coarse costellae of strength comparable to those of *L. pollex*, whereas those described by CHAO are reported to have as many as 10 to 11 costellae in 5 *mm.*, as in the Russian specimens.

Apart from the absence of a flaring anterior trail, there is considerable resemblance in shape to *Productus productus* (MARTIN) (see MUIR-WOOD, 1928, 1930), but the absence of concentric wrinkles from the posterior part of the ventral valve of *L. pollex* suggests that this resemblance is only superficial. According to MUIR-WOOD and COOPER (1960, p. 239) the internal details of the ventral valve of MARTIN's species are still not known.

Tomiproductus tomikhensis SARYČEVA in SARYČEVA *et al* (1963, p. 206, pl. 32, figs. 8—13) is similar in general shape and massive shoulders, but is not considered congeneric, as it has a thicker disc, wrinkles over the ventral valve, lacks the very fine radials of the new species, and has productoid ridges over the ventral adductor platform. *Tomilia* SARYČEVA is also superficially similar, but also probably does not even belong to the same family.

The Mississippian *Ovatia elongata* MUIR-WOOD and COOPER (1960, pl. 114, figs. 1—4, 7, 11, 12) is more or less similarly elongated with steep posterior walls, but has slightly finer ornament and no median sulcus. An anterior median sulcus is seen in one of the specimens figured as *?Cancrinella ovata* HALL (not PANDER) by SARYČEVA and SOKOLS'KAJA (1952, pl. 19, fig. 132). Details of the dorsal exterior and ventral interior differ significantly in *Ovatia*.

Genus *FUSELLA* McCOY (1862)

Type species: *Spirifera fusiformis* PHILLIPS (1836).

Diagnosis: Mucronate throughout ontogeny, with ornament of costae over sulcus, fold and lateral slopes except parts of ears, some branching, most simple, surface, covered by fine longitudinal filae. Dental plates supported by short adminicula, dorsal valve with crural and socket plates, no adminicula.

Discussion: The genus is based on a single specimen of moderate preservation, as figured in PHILLIPS (1836, pl. 9, figs. 10, 11), DAVIDSON (1858, pl. 13, figs. 15 a, b) and BROWN (1849, pl. 51, figs. 4, 5). IVANOVA in SARYČEVA (1960, p. 269) included the species *tornacensis* DE KONINCK in the genus, thus altering the concept of the genus forwarded by BUCKMAN (1908), who considered that the ribs tended to be deficient medianly and that the type is in the smooth stage, when usually all the ribs have been lost. BUCKMAN referred species of several genera to *Fusella*, including forms that belong to the plicate alate genus *Brachythyrina*, which, like *Brachythyris* and

Martinia, lacks ventral adminicula. If IVANOVA's interpretation is correct, *Unispirifer* CAMPBELL (1957) is almost certainly a synonym, as noted by IVANOVA. The type species of *Unispirifer* is *Spirifer striato-convolutus* BENSON and DUN (1920). As a recently described genus, it is easier to recognise than *Fusella*, though cardinal details were scarely described by CAMPBELL, making with the poor reproduction of his figures, it difficult to be certain that the Nepal form is exactly comparable. Another source of doubt stems from the exact nature of the costation within the sulcus. CAMPBELL stressed, and perhaps exaggerated the significance of a median sulcal costa, which he emphasized is invariably present, and arises at the umbo. A median costa is present on the Nepal form, but is absent from the umbonal tip. A point of uncertainty lies in the nature of the hinge, which is denticulate in *Unispirifer* but not known in the Nepal specimens owing to poor preservation.

Austrospirifer GLENISTER (1955) from the Middle and Upper Devonian of Western Australia is apparently close, but GLENISTER stated that the dental plates are attached only to the posterior wall, and not, or only very slightly to the floor of the valve, and CAMPBELL (1957) considered that the genus differed from *Unispirifer* in its absence of hinge denticles, and failure of the plicae, or costae, to branch.

Fusella mucronata n. sp.

Pl. 15, fig. 1; Pl. 16, figs. 1—4, 6, 8

? 1903 *Spirifer* sp. indet. ex aff. *curzoni* DIENER, p. 150, pl. 7, fig. 7.
? 1903 *Spirifer* cf. *strangwaysi* DIENER, p. 146, pl. 7, figs. 8 a, b.
? 1915 *Spirifer* sp. ind. (cf. *bisulcatus* SOWERBY) DIENER, p. 8, pl. 1, fig. 5.

Material: A specimen with valves conjoined and a ventral valve, leached in acid to show internal details, from F 127, and posterior fragments of four worn ventral valves from F 67.

Holotype: Specimen figured in pl. 16, figs. 1, 2, from F 127.

Diagnosis: Transverse shells with outwardly curved costae, sulcal costae arising some distance in front of umbo, ears large.

Dimensions (in *mm.*):

Width	Length	Length Dorsal	Height Ventral	Height Dorsal	Umbonal Angle	Cardinal Angle	Sulcal Angle
			F 127				
+45	19.5		10.5		85°	30°	20°
+62	27	23	9	5.5	100°	20°	24°

Collection Number	Width	Muscle field Width	Muscle field Length	Adductor Width
		Internal		
F 127	45	4.8	6	0.6
F 67	+29	8.0	7.5	1.1

Description:

External: The two specimens from F 127 are transverse and moderately inflated, with a moderately low, incurved ventral umbo, and concave interarea interrupted by a triangular delthyrium with an angle of 60° both in a

specimen from F 127, and in one from F 67. Laterally the interarea stands at about right angles to the commissure on the holotype, and is marked by very fine vertical and longitudinal striations. The dorsal umbo is inconspicuous and the dorsal interarea seemingly very low. Growth lines show that the ears are extremely attenuated, with a low angle of about 20° — it is thus probable that the holotype measured at least 80 *mm.* in width. The ears are gently convex, and separated from the body of the shell by a low depression which passes into a recession at the commissure. In front the outline is gently rounded, with no distinction between the lateral and anterior margins. A shallow sulcus commences at the ventral umbo and widens and deepens steadily to the anterior margin, but remains shallow with a concave floor. The dorsal fold is very low. Both valves are covered by coarse costae, numbering about 30, with low well rounded crests and somewhat narrower interspaces. They curve outwards laterally, and possibly arise by bifurcation, though instances are rare, and most costae commence close to the umbones. At least six occur within the sulcus anteriorly, but their mode of origin, as for those of the dorsal fold, is obscured by damage and matrix. A prominent median costa arises 3 to 4 *mm.* in front of the umbonal tip. The posterior part of the ears is marked only by growth lines, but costae commence laterally in front of prominent growth-lines on the dorsal valve of the holotype. The shell surface is also covered by fine longitudinal filae, about 7 per millimetre, crossed at intervals of about 1 *mm.* by growth lamellae.

Internal: In the leached ventral valve from F 127 a low convex delthyrial filling marked by arched and continuous growth-lines underlies the umbo. The posterior part passes laterally into a deep groove which borders the delthyrium, and is separated from the interarea by a narrow ridge, followed by a narrow groove. The anterior part of the filling tapers laterally, to adjoin low dental plates, concave inwards, and supported by short high subparallel adminicula which pass down the posterior wall to rest on the floor of the valve. They are wedge-shaped, tapering anteriorly to end in a thin blade. A narrow groove passes across the delthyrial filling and down the posterior wall, but does not reach the muscle field. The muscle field is short and broad, with a low median ridge, between two concave adductor impressions, each divided from the diductors by another low ridge. Anteriorly these all break up into several fine ridges and grooves. To each side the diductor impressions are lightly marked by very fine longitudinal striae, as well as occasional growth rugae parallel to the anterior margin. The posterior walls are dimpled, with rounded pits each a little less than 1 *mm.* apart and to each side of the muscle field the floor of the valve is also marked by a few low radiating ridges. Much finer pits and pustules seem to cover the entire floor, about 12 occurring per millimetre.

In the best preserved of the ventral valves from F 67, the muscle field is larger, the adductors of the same pattern, and the diductors more heavily striated longitudinally. Deep pits lie over the posterior wall, and behind the muscle field the posterior wall is depressed into a triangular pit marked by fine vertical striations. Adminicular plates are very broad and short. The other two specimens lack deep pits over the posterior wall, and have a simple concave triangular filling beneath the delthyrium. On one the myophragm is broad posteriorly and very narrow in front, and the diductors are

crossed by oblique grooves passing postero-laterally. A median groove passes for a short distance down the posterior wall between two subquadrate thickenings. The two specimens may be variants of the species, having a similar broad muscle field and short adminicula, or may belong to another species.

Resemblances: The specimen described from the Syringothyris Limestone of Kashmir by DIENER (1915) is tentatively referred to this species, because it is similarly transverse and comes from much the same horizon as the types. It has a lower umbonal region, and its outline is possibly less retracted beneath the ears, and the sulcus seems to be slightly deeper. The sulcal costae seem to be somewhat more clearly exposed than in the types so that examination should enlarge understanding of the species.

The genus is apparently represented by several specimens from the flaggy Carboniferous limestone of the Spiti section. Inspection at Calcutta of the specimen considered by DIENER (1903) to have affinities with *S. curzoni* showed that it has costae over the fold, and traces of 7 to 8 radial filae per millimetre as in the Nepal specimens, and strong concentric lamellae. The ventral valve figured as *Spirifer* aff. *strangwaysi* by DIENER comes from the same locality, and has the same ornament, without a median costa, according to the figure.

From the same limestone DIENER (1903, p. 151, pl. 7, figs. 12 a—d) also recorded two specimens as *Spirifer (Ambocoelia?)* sp. ind. aff. *fusiformi* PHILLIPS, but the Spiti specimens lack alate extremities, as noted by DIENER, and are probably not closely related.

Of other forms one of the closest appears to be *F. striatoconvolutus* (BENSON and DUN, 1920, pl. 20, figs. 7, 8) also described by CAMPBELL (1957, pl. 14, figs. 1—9; text-figs. 10 a, 11, 12) from the Middle and Upper Tournaisian beds of the Lower Burindi Group, Australia. This is almost as transverse as the new form, but has less outwardly curved lateral costae, and is said to become less transverse with increase in size, whereas the opposite appears to be true for the new species, although of course it may not be fully mature and may have increased in length at a later stage of growth. The ears are less developed on the Australian species. According to CAMPBELL (1957, p. 67) only the median sinal costa and a primary costa each side arise at the umbo (though in his main description the median costa is stated to arise within 'a few *mm.*' of the umbo). In the holotype of the new form several costae arise very close to and probably at the umbonal tip, and the median costa arises within a few millimetres from the tip.

Spirifer fusiformis is also close in its transverse outline, but would appear from the figures of the type specimen to have a higher ventral interarea, and more prominent dorsal fold. Many other details are not known.

F. kondomensis BESNOSSOVA and *F. osipovensis* BESNOSSOVA in SARYČEVA *et al* (1963, pl. 52, figs. 3—6) are moderately transverse, but are distinguished from the new species by their slightly less alate cardinal extremities and more diamond-shaped outline.

Other specimens are less transverse, including the Yunnan specimen considered to be a variety of *tornacensis* by REED (1927, pl. 10, fig. 2). As figured by de KONINCK (1887, pl. 25, figs. 1—13) *F. tornacensis* is certainly

close, with ears that increase in size, but is slightly less transverse at even early stages of growth, and has less outwardly curving costae.

The Lower Carboniferous form from Japan named *Fusella nippotrigonalis* by MINATO (1951, p. 372, pl. 2, fig. 5) lacks costae from the dorsal fold and so is not congeneric.

Genus *EOMARTINIOPSIS* SOKOLSKAJA (1941)

Type species: *Eomartiniopsis elongata* SOKOLSKAJA (1941).

Diagnosis: Oval shells with brachythyrid hinge, sulcus, fold and very fine surface pits, no plicae or costae. Ventral adminicula long and subparallel, adductor ridges as in *Martiniopsis*. Dorsal adminicula very short.

Eomartiniopsis cf. *helenae* SOKOLSKAJA (1941)

Pl. 16, fig. 5

Material: Ventral valve from F 67, leached in hydrochloric acid to show internal and external details.

Dimensions (in *mm.*):

Width	Length	Height	Umbonal Angle	Adminicula Length	Adminicula Apart	Adductors Width	Sinal Angle
+16	+19.5	8	?110°	5.1	6.2	1.0	10°

Description:

External: The shell is probably subpentagonal in outline, with a broad slightly incurved umbo and moderately wide hinge and obtuse cardinal extremities. The specimen has been reduced in width and increased in height by distortion. Its ventral interarea is feebly defined, and interrupted by a delthyrium which is somewhat arched immediately under the umbo, with an angle of less than 40°.

The shell is smoothly convex apart from a narrow median sulcus which is rather angular in cross-section and commences possibly as a narrow groove over the umbo and deepens rapidly beyond the posterior third. Some longitudinal rugae are present on one side but these are probably due to distortion. Surface ornament consists of minute pits, 15 to 20 per millimetre, lying in concentric rows.

Internal: The delthyrial filling lies below the interarea from which it is separated by a deep groove to each side. It is weakly convex near the commissure, and has a large umbonal callosity which forks anteriorly. Dental and adminicular plates lie in the same plane, passing vertically to the floor of the valve, and heavily thickened posteriorly, so that they are wedge-shaped. The adductors consist of two narrow ridges separated by a median groove. Diductor impressions are lightly striated by longitudinal grooves, and are deeply depressed below the rest of the floor. Vascular or goniophore pits and dimples lie over the posterior floor.

The posterior shell is about 1.5 *mm.* thick.

Resemblances: The extreme fineness of the ornament, the alignment and shape of the dental and adminicular plates, and the nature of the delthyrial

filling distinguish the specimens from Permian species of *Martiniopsis*. In most respects the specimen appears to belong to *Eomartiniopsis*, but of course the absence of the dorsal valve prevents certain identification. In the rounded, non-extended cardinal extremities, and the way in which the sulcus commences in front of the umbo, and deepens rapidly, the specimen compares well with *E. helenae* SOKOLS'KAJA.

Of other species perhaps the closest is *E. maximovae* BESNOSSOVA in SARYČEVA *et al* (1963, pl. 57, fig. 9), but the sulcus of this commences in a more anterior position, and is wider at the anterior commissure.

Genus *SYRINGOTHYRIS* WINCHELL (1863)

Syringothyris curzoni (DIENER, 1903) *glaber* n. subsp.

Pl. 16, figs. 6–8

Material: Single large ventral valves from F 67 and 127, and two small ventral valves from F 67.

Holotype: Specimen figured in pl. 16, fig. 7, from F 67.

Diagnosis: Closely allied to *S. curzoni* (DIENER, 1903) in faintness of ventral ornament, and position of syrinx, and low dental plates almost in the plane of the adminicula, distinguished by less transverse shape, narrower sulcus, longer more widely diverging adminicula, and diductors with fewer markings.

Dimensions (in *mm.*):

Collection Number	Width	Length	Height	Adminicula Length	Adminicula Apart
127	36	45	10.5		
67	15		6	9	3
67	26	31.5	15	25	5.5

Description:

External: The specimens are characterised by a long protruding ventral umbo, of which the angle measures about 80°, extended low posterior walls concave in outline towards the posterior margin, and obtuse cardinal extremities in front of which the shell is well rounded in outline. The position of maximum width appears to have been just in front of the hinge, but this is not certain because of distortion. The interarea is high, concave and incurved, with a triangular shape, and occupied for the middle sixth of its length by a delthyrium. The interarea of the small specimen from F 67 which may belong to the subspecies has deep vertical grooves, about 3 per millimetre, and a narrow high delthyrium with an angle of only 25°. Fainter vertical grooves appear on the large internal mould, 2 to 3 per millimetre. No ears are differentiated. A narrow sulcus with an angle of about 8° commences at the umbo and persists to the anterior margin, with a very gently concave floor. The small specimen with strong vertical markings on the interarea has two plicae anteriorly one each side of the sulcus, but whether these are due to distortion or to represent an unusual feature of the species, or show that the specimen is not conspecific, is not certain. There are faint traces of broad low costae on one side of the large

leached specimen, about 3 costae occurring in 5 *mm.*, but on other specimens the surface of the shell is smooth apart from traces of low growth-lines. The nature of fine surface ornament is not known for certain, but fragments of worn shell appear to be closely pitted, with about 10 pores per millimetre.

Internal: Two specimens show details of the interior. In the large specimen the plates supporting the teeth pass converge slightly from the teeth, and then diverge by about 20° to meet adminicula diverging at 20° to the floor of the valve, with thick bases over 2 *mm.* wide posteriorly. With the heavy posterior thickening they appear to diverge from the posterior wall, and are subparallel for most of their length, with slight inward concavity, so that they converge a little anteriorly. Between the plates and next to the delthyrial filling lies the hollow tubular syrinx, with a median groove along its ventral surface, and a thick low septum with a wide dorsal base on its dorsal surface. A low median septum traverses the muscle field, as well as a few broad low ridges and shallow longitudinal grooves laterally, but there is no clear differentiation into adductors and diductors. To each side of the plates the floor of the valve is practically smooth apart from fine slightly elongated pustules.

The other specimen differs considerably and is either not related or represents an early stage of development. Plates supporting the teeth are long, and diverge slightly to the floor of the valve at about 50° and anteriorly by about 10°. There is no obvious distinction in angle of inclination between dental and adminicular plates. In between these plates are two sturdy plates that diverge away from the floor of the valve to fuse under the delthyrial filling, forming a surface concave dorsally, that slopes dorsally from the posterior floor. The surface is lined by arched growth-lamellae and traversed longitudinally by a median ridge. There is no median hollow tube. Another point of divergence from the large specimen is that the muscle field is deeply depressed below the floor of the valve to each side.

Resemblances: Few specimens of *Syringothyris* are so nearly smooth as these valves from Nepal, apart from decorticated shells such as the one figured as *S. hannibalensis* (Swallow) from the Louisiana Limestone by Weller (1914, pl. 68, fig. 4). However specimens collected from the upper Syringothyris Limestone at Kotsu Hill, Kashmir, by Dr. G. Fuchs (K 22) are comparable, with very low, or seemingly no costae. By comparison the dorsal valves from the same locality have much more obvious costae, so that the faintness of the ornament would seem to reflect the original nature of the shell, and not just be due to decortication. The dental plates are short and lie almost in the same plane as the adminicula, as in the Nepal specimens, and the syrinx occupies a similar position, whereas it lies closer to the floor of the valve and dental plates are much higher in *S. lyddekeri* Diener. On the other hand the Kashmir specimens are more transverse, and the adminicula are shorter and diverge more anteriorly, and diductors are marked by better defined transverse ridges and grooves than in the Nepal specimens. Other Kashmir specimens were described as *S. cuspidata* Martin from Eishmakam by Diener (1915, p. 9, pl. 1, figs. 6—8), the figured specimens being slightly transverse to elongate, with moderately to weakly defined costae, and a wider sulcus than in the Nepal specimens, suggesting that the adminicula are also likely to diverge more. Diener's figures are certainly close to figures

of *cuspidata* offered by DAVIDSON (1858, pl. 8, figs. 19—24), though the European specimens generally have more obtuse cardinal extremities, and slightly stronger sometimes broader costae. Specimens ascribed to the same species from limestone below the Kuling shales near Kuling by DIENER (1899, p. 76, pl. 4, figs. 9, 10) are transverse with low costae, and coming from an identical horizon, are likely to be conspecific, though details of their morphology are poorly known. In 1903 DIENER referred the Syringothyris Limestone specimens to a new species, *Spirifer curzoni* (1903, p. 147, pl. 7, figs. 2—6), supposing that a syrinx was absent. But the presence of a syrinx and punctation was established for the species by HAYDEN in the same work, and the species abandoned in favour of *cuspidata*. Not having specimens of *cuspidata* before me, I am unable to assess the extent to which DIENER's species is really distinctive. Whatever its validity, it seems clear that the Nepal shells are closely related to the Kashmir specimens, yet are distinguished by their narrower sulcus, less widely diverging adminicula, different muscle scars, and fainter ornament of the ventral valve. This is perhaps best expressed by referring the Nepal shells to a new subspecies.

The new form is perhaps equally close to *Syringothyris serenae* SOKOLSKAJA, which lacks radial ornament. As figured by SARYČEVA and SOKOLSKAJA (1952, pl. 63, fig. 356) it is more transverse, with alate cardinal extremities and a deeper wider sulcus, and the suggestion of more widely diverging adminicula.

Syringothyris skinderi SOKOLSKAJA in SARYČEVA *et al* (1963, p. 275, pl. 47, figs. 3—7) has low to moderately strong ornament, but again is decidedly transverse with a deeper wider sulcus.

Genus *PUNCTOSPIRIFER* NORTH (1920)

Punctospirifer sp.

Material: A ventral valve from F 127.

Dimensions (in *mm.*):

Width	Length	Height	Umbonal Angle	Cardinal Angle	Sinal Angle
8.5	9.5	3.7	85°	?120°	17°

Description: The specimen is a small elongated ventral valve with posteriorly extended umbo, concave posterior walls, maximum width placed behind mid-length, and a moderately deep sulcus, rather U-shaped in cross-profile, and bearing a low median costa. The lateral extremities are possibly lost. There are four pairs of outwardly curving plicae, of which the innermost pair bordering the sulcus is by far the most prominent. The shell is traversed by low even growth wrinkles, of which about 4 occur per millimetre, as well as traces of much finer concentric filae, about 12 to 15 per millimetre. There are also fine longitudinal filae, about 10 to 12 per millimetre measured within the sulcus. The shell is pierced by about 7 pores per millimetre, more or less in concentric rows, 8 rows being counted in 1 millimetre at mid-length on the plication bordering the sulcus.

Discussion: Although the specimen is tentatively referred to *Punctospirifer* because of the apparent absence of spines and presence of radial threads these observations require confirmation from better preserved material, and the generic position of the specimen is highly uncertain. Never-

theless, the specimen is comparable to a few species described as *Punctospirifer* from more or less comparable horizons of the U. S. S. R. Of *Punctospirifer* figured in SARYČEVA and SOKOLSKAJA (1952) the closest is *P. partitus* (PORTLOCK), with similar prominent umbo and median costa and high inner plicae. *Punctospirifer orlowi* ČERNYAK in DEDOK and ČERNYAK (1960, p. 67, pl. 9, figs. 7, 8) from C_1^d beds of Taimyr Peninsula also has an extended ventral umbo and narrowly diverging posterior walls, a sulcal costa, and low lateral plicae. No comparable specimens appear to have been described from the Syringothyris Limestone of Kashmir, or Lipak beds of Kanaur and Spiti.

Correlation of the faunas

1. Permian

A. Interrelationships of the faunas.

As shown in Table 1, most of the Permian fossil localities have a more or less similar fauna, with no unique species (F 58, 94, 129, 130, 147, 148, 117). Faunas at the top of the succession, especially F 112 and 108 have several species not found in underlying beds, partly at least because of facies, the uppermost beds being more calcareous. No definite difference in age can be established. A sandstone and mudstone fauna from F 105, apparently with obscure relationships to the remainder of the column, has a species akin to a Lower Permian species, *Syringothyris lyddekeri*. Associated species point to an Upper Permian age, though none are very well preserved, and *S. lyddekeri* supposedly has Upper Permian representatives, so the fauna is presumed to be of approximately the same age as the others.

B. Correlation with other faunas

Himalaya

The Permian faunas from Nepal are correlative in a general way with the Himalayan faunas described from the Zewan beds of Kashmir, the Productus Shales of Kumwaon and Garwhal, the Kuling Shale and underlying sandstone of Spiti. Closest affinities lie with the Zewan faunas, followed by those of the Productus Shales, and there is less resemblance to the moderately distinctive limestone faunas from Chiticun 1 and Malla Sangcha. Most of these faunas have been rather lumped in the descriptions, so that it does not seem possible to make refined correlations with any particular zone within these faunas. The zonation proposed for the Zewan succession by HAYDEN and MIDDLEMISS is scarcely reflected in the Nepal sequence. According to the scheme outlined by DIENER (1915) the basal zone is dominated by *Marginifera himalayensis*, with *Anidanthus waagenianus* (= *fusiformis*) prominent, accompanied by *Neospirifer moosakhailensis*, *Fusispirifer nitiensis*, *Spiriferella rajah*, and *Hoskingia latouchei*. The middle zone is dominated by *S. rajah* and has *N. moosakhailensis*, and the uppermost zone contains *Xenaspis*, various bivalves, *Waagenoconcha purdoni*, *Costiferina indica*, and rare *A. fusiformis*. DIENER stressed that there is not much difference in age between the zones. The Nepal faunas come closest to those of the basal zone, but do not fall into a zonal sequence comparable with that of the Zewan succession. *Marginifera* comes in near the top of the Nepal

Species	Nepal Fossil Locality											Middle Productus Limestone	Upper Productus Limestone	Chitichun	Malla Sangcha	Zewan	Kuling Shales	Productus Shales Lissar	Sandstone below Kuling	Lachi Series	Chitrai	Basleo Beds	Aler Mati	Other regions
	58	105	94	129	130	147	148	117	112	113	108													
Orthotetes bisulcata n. sp.									×					?										
?*Neochonetes* spp. indet.	×										×									aff	cf			
Multispinula indica (WAAGEN)									×			?	×											
Krotovia opuntia (WAAGEN)											×		×									cf		Up. Perm. North Caucasus
Marginifera sp.											×	22	2	2	1·2	1	1	1		1	cf	?2		Up. Perm. Karakorum
Anidanthus fusiformis n. sp.	×	×							×		×	aff		×		×					cf			
Waagenoconcha purdoni (DAVIDSON)	×								×			×	× ×			×		×		?		×	? ×	
Costiferina alata n. sp.	×				×								aff			aff								
Linoproductus lineatus ? (WAAGEN)		×										?	?			?					aff			North Caucasus Mongolia etc.
Dictyoclostid sp. indet.									×															
Neospirifer moosakhailensis (DAVIDSON)			×	?	×		×			×	×	×	×	×	×	×	×	×	×	×	×	cf	cf	Madagascar Tibet
N. ravana (DIENER)									×			cf	cf				cf	×	×					
Fusispirifer nitiensis (DIENER)	×									×								×	×					
Spiriferella rajah (SALTER)	?					×		×								×	×	×		×	cf	aff	aff	Tibet
S. tibetana (DIENER)					×						×			×	×							cf		Up. Perm. Karakorum
Martiniopsis sp.		×											aff										aff	aff, Shan Anthraco-lithic
Syringothyris lyddekeri ? (DIENER)		×															?			?				Laddakh Sandstone Karakorum
Punctospirifer sp.											×		aff	aff		aff								
Cleiothyridina subexpansa (WAAGEN)									×		×	× ×	×	×		×					×			
Hoskinigia latouchei (DIENER)		×														×		×	×					
Number of Species...	6	5	1	1	3	1	1	1	7	2	8	3	5	4	2	6	2	6	4	3				Identical species
Unique species (in Nepal)...	0	4	0	0	0	0	0	0	4	0	3	5	5	2	1	4	2	1	0	3				Allied species

× = occurrence of species
cf = comparable species

aff = species with affinities
? = possibly identical

1 *Marginifera himalayensis*
2 *M. typica*

sequence, *Anidanthus fusiformis* occurs at the bottom and top, *Waagenoconcha purdoni* at the bottom and near the top, *N. moosakhailensis* ranges throughout, *F. nitiensis* at the bottom and top, *Spiriferella* bottom and middle, and *Hoskingia latouchei* at the base, the latter two as in the Zewan beds.

At Spiti the distinction between the faunas of the Kuling Shales at the top of the sequence, and the underlying sandstone has been masked by mixture of collections, but even so, DIENER considered there was little difference in age between the two faunas. Three prominent spiriferoids of the Nepal faunas are more characteristic of the sandstone, *N. moosakhailensis*, *N. ravana*, and *F. nitiensis* as well as the Dielasmatid *H. latouchei*. *S. rajah*, amongst other forms, is found only in the overlying Kuling Shale. Yet in the Nepal sequence, the order is in part reserved, *S. rajah* preceding *N. ravana*, and both are preceded and followed by *F. nitiensis*. No doubt facies has helped to determine the appearance of the fossils, and there may be no time significance at all. This lack of time significance appears to be supported by the occurrence of all four spiriferoid species together in the Productus Shales.

In early work DIENER (1897 a) favoured a slightly older age for the Chiticun faunas, which he correlated with the upper Middle Productus Limestone, compared with an Upper Productus Limestone correlation for the Productus Shales, though this could not be firmly established (1897 b). The Zewan faunas were also regarded as somewhat older than the Productus Shale faunas (DIENER, 1899). Since the Nepal faunas have *Spiriferella tibetana* in common with the Chiticun fauna, and agree well in other respects with the Zewan fauna they might be a little older than the Productus Shales, which are considered to lie at the top of the Paleozoic sequence, not divided from the basal Triassic by any visible unconformity. More recently however the Chiticun and Zewan faunas have been regarded as approximately contemporaneous with the Kuling and Productus Shales faunas. DIENER (1915) thus revised his correlation of the Zewan faunas which he came to consider closest to those of the Productus Shales, and MUIR-WOOD (1941) also treated them all as roughly contemporaneous. Of importance in this regard is the discovery of the ammonoids *Cyclolobus* and *Xenaspis* at both Chiticun 1 and in the Kuling Shales (DIENER, 1915), *Cyclolobus* in the Productus Shales (PASCOE, 1959, p. 810) and *Xenaspis* in the upper Zewan beds (DIENER, 1915). *Xenaspis* does enter the Salt Range succession earlier than *Cyclolobus*, so that the Zewan beds could be a little older than the others, but, in view of the brachiopod affinities, not to any significant degree.

Correlation with the Salt Range Succession

In 1903, although reporting the occurrence of *Cyclolobus*, DIENER retained his upper Middle Productus correlation for the Chiticun 1 faunas because NOETLING had found *X. carbonarius* to be prolifically represented at this horizon in the Salt Range. However *Xenaspis* extends into the Upper

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TABLE 1:

Chart of brachiopod occurrences in the Permian of Nepal and nearby areas. A symbol doubled in either the Middle or Upper Productus Limestone column shows where the species is more abundant.

Productus Limestone (REED, 1944, p. 505), and correlation with this high horizon is generally preferred, MUIR-WOOD (1941) accepting such an age for the Productus Shale at the top of the Kuling Series, and stating, without giving detailed reasons, that the Lachi Series was equivalent to the Upper Productus Limestone. REED (1944, p. 376) accepted an Upper Productus correlation for the Kuling Shales, and a Middle Productus correlation for the underlying sandstone. Although as indicated there is some meagre faunal evidence to suggest that the Nepal brachiopod faunas need not be quite as young as the uppermost Productus Shale, Kuling and other faunas, there is a slight preponderance of Nepal species in common with the Upper rather than the Middle Productus Limestone. Not one of the Nepal series is restricted in the Salt Range succession to the Middle Productus beds, whereas two species high in the Nepal sequence, *Multispinula indica* apart from a doubtful occurrence, and *Krotovia opuntia*, do not occur below the Upper Productus Limestone in the Salt Range. The tendency for *Cleiothyridina subexpansa* to be more characteristic of the Middle Productus Limestone is counterbalanced by *Waagenoconcha purdoni*, which is more abundant in the upper division. Other affinities are summarized in the chart.

Chitral

Some similarities apparently lie with the succession two miles north of Baroghil Ailak in the Chitral province, though REED (1925) identified *Fusulina* and *Schwagerina princeps* and assigned an upper Carboniferous, or what would now be Lower Permian age. The overall appearance of the brachiopods except for some of the productids and molluscs, especially the gastropods, is suggestive of a higher horizon, but I have had no opportunity to examine the fusulinids which must be decisive.

Karakorum

Considerable similarities exist between the faunas of Nepal and the Karakorum, but a full comparison has been hindered by my inability to examine the faunas at first hand, and the lack of some literature. From the Remo Valley PASCOE (1959, p. 803) quoting PARONA (1932), and DE TERRA (1932), lists *Anidanthus aagardi*, *Waagenoconcha purdoni*, *Neospirifer moosakhailensis*, *Marginifera himalayensis*, and *Spiriferella tibetana*. (Names are changed to accord with current nomenclature.) From near the source of the Shyok, GORTANI (1920) listed faunas equivalent to the lower of the two Productus Shale zones, including *A. aagardi*, *M. himalayensis*, *S. tibetanus*, *S. interplicata*, *Syringothyris* aff. *lyddekeri*, *Cleiothyridina subexpansa*. In the same area a higher horizon has yielded *Linoproductus lineatus*. From the Lopingian beds of Rimu, Karakorum, MERLA (1934) described *W. purdoni*, *M. himalayensis*, *S. tibetana tenuisulcata*, *N. moosakhailensis*, *S. lyddekeri*, in name at least close to the Nepal faunas, though the small size of the specimens precludes much certainty in identification. Some of the specimens described from his Lower Permian show some affinity, including varieties of *S. tibetanus*, and *Anidanthus* cf. *waagenianus*, and *A. aagardi*. RENZ (1940 a, b) listed or figured *Marginifera himalayensis*, *Linoproductus lineatus*, *Neospirifer moosakhailensis*, *Fusispirifer nitiensis*, *Spiriferella tibetana* and *occidentalis* from the Permo-Carboniferous of the Karakorum.

Tibet

Spiriferella rajah has been identified from the Mount Everest region, and TING PEI-CHEN (1962) has described an upper Permian fauna from the Kubei and Tsunbu districts with shells closely related to or identical with *Costiferina alata*, *Neospirifer moosakhailensis*, and *Spiriferella vercherei*.

Burma

The Kehsi Mansam fauna of the Southern Shan States described by DIENER (1911) includes shells identified as *N. moosakhailensis* and *Strophalosia* cf. *indica*, as well as *Martiniopsis latouchei* and *Linoproductus lineatus* which are close to Nepal specimens. The identification of *Polydiexodina* by DUNBAR (1933) suggests an Upper Permian age, but the fauna belongs to a slightly different province. The Mongolian faunas described by GRABAU (1931), and various faunas from China have several species in common with or allied to Nepalese forms.

Further correlations

As shown in Table 1, most of the remaining similarities lie with Productoid species recorded from the North Caucasus by LIHAREV (1936) and ABICH (1878), and from the Basleo and related beds of Timor and Ajer Mati. The Timor affinities have been treated somewhat cautiously in this work, and it is probably that differences between the forms from the two realms are of no more than subspecific rank. Correlation is strengthened by an Upper Productus *Cyclolobus* ammonite fauna in the Amerassi beds of Timor (GERTH, 1950, p. 258), and GERTH (1950, p. 255) stated that *Cyclolobus*, and *Xenaspis* first appeared in the Basleo or *Timorites* Stage.

A related fauna appears just below the Triassic in Madagascar, again with *Cyclolobus* and *Xenaspis*.

C. Age of the Nepal Permian Faunas

The faunas with which the Nepal brachiopods are matched are widely assumed to be of topmost Permian age, Tatarian in the world standard sequence, or belonging to the *Cyclolobus* zone of ammonoid subdivisions (GLENISTER and FURNISH, 1961). As outlined above, there is some possibility that the Nepal faunas are slightly older, but not to any significant degree, and it seems likely that the faunas do belong to the *Cyclolobus* zone of MILLER and FURNISH (1940). This ammonoid, frequently accompanied by *Xenaspis*, is known at the top of the Permian succession, and immediately below the basal Triassic in the Himalayan region, the Salt Range, Madagascar, Timor, and Greenland.

Nevertheless, in spite of widespread consensus of opinion on the *Cyclolobus* zone, some problems arise from granting it such a young age. The question is too lengthy to be fully discussed here, but I would raise some arguments, far from conclusive, to emphasize other aspects of the problem. In the first place, the chief stress on the young age of the *Cyclolobus* ammonite group comes from some American workers, who with a very imperfect Upper Permian sequence, have also stressed the young age of the *Yabeina* Fusulinid zone (THOMPSON, 1948), and have been followed in this regard by some, but

not all Japanese workers. On the other hand SHENG (1963) has recently criticised this correlation for *Yabeina* and its allies, and shown that the *Yabeina* zone is followed by two further very clearly fusulinid zones in Kueichow and other parts of China. It is possibly significant that the *Neoschwagerina — Yabeina* zone in the New Zealand Permian sequence (HORNIBROOK, 1951) is followed by beds with *Xenaspis carbonarius* (WATERHOUSE, 1964 a, b, d) the ammonoid which comes in just below and accompanies *Cyclolobus*. Above *Xenaspis* in New Zealand come two distinct brachiopod zones, below the basal Triassic. The *Yabeina* and *Xenaspis* were regarded by WATERHOUSE (1963) as being lower Upper Permian.

One of the most arresting features of the brachiopods, bivalves and gastropods accompanying the *Cyclolobus* zone is that they differ little from those of supposedly significantly older faunas. Thus the Greenland brachiopods and bivalves were considered by DUNBAR (1955) and NEWELL (1955) to be Zechsteinian in affinities, or supposedly Kazanian apart from the *Cyclolobus*. Only the presence of *Cyclolobus* compelled a topmost Permian age, as in DUNBAR (1962, et al. 1960, 1962). Basleo brachiopods do not differ significantly from those of slightly higher Indonesian faunas, and GERTH (1950) reported *Cyclolobus* from the Basleo beds, which are generally referred to the *Waagenoceras* zone, or Kazanian Stage. In the Salt Range the faunas of the Upper Productus Limestone differ scarcely at all in overall appearance from those of the Middle Productus Limestone, WAAGEN wishing to include the upper part of the Middle Productus Limestone in the same major unit. By contrast the topmost fauna of the New Zealand succesion is particularly distinct from that the *Yabeina-Xenaspis* faunas below (WATERHOUSE, 1964 d, in press). Uppermost faunas from Japan contain most unusual bivalves (Prof. N. D. NEWELL, pers. comm.). It seems just possible that part of the sequence is missing from the Salt Range, Nepal, and other regions, in spite of the evidence based on ammonite sequence and evolution. Such a gap is certainly not obvious in the field — Dr. FUCHS has emphasized the conformity of the succession in Nepal, and I have seen and admit the apparent continuity of the sequence in the Salt Range, even though KUMMEL and TEICHERT (1964) have found some evidence for reworking of Permian fossils in the supposed basal Triassic. The thesis that time is unrepresented in the column is certainly one hard to support from the field, and must be regarded as an unsubstantiated hypothesis at this stage.

2. Carboniferous

The older faunas from the Upper Paleozoic of Nepal are Lower Carboniferous, and probably Upper Tournaisian in age. Closest resemblances lie with the fauna of the Syringothyris Limestone of Kashmir and the Lipak beds of Kanaur and Spiti (DIENER, 1899, 1903, 1915), with *Linoproductus pollex* and *Fusella mucronata* in common, and *Eomarginifera* and *Syringothyris* closely allied, and perhaps identical to specific level. The fauna of the Syringothyris Limestone differs considerably from Visean faunas of China, Siberia, and Malaya (MUIR-WOOD, 1948) and is generally considered to be Tournaisian. This age is reinforced by the affinities of the Nepal species. The genus *Fusella* is especially characteristic of the Tournaisian of Europe

and is found in Tournaisian beds of Australia, and *Eomartiniopsis helenae* and *Syringothyris setenae* are listed in SARYČEVA and SOKOLŠKAJA (1952) as coming from the basal Carboniferous C^{ml} and C^{tsch}. *Rhipidomella* approaches *R. michelini*. These correlations appear sufficiently firm to withstand Productoid evidence for a slightly younger, perhaps Visean age, suggested by *Eomarginifera's* similarity to *E. longispina* which is chiefly Visean and Namurian, and *Linoproductus* for which MUIR-WOOD and COOPER (1960, p. 298) list no species older than Upper Carboniferous. Not that Productoids are considered to be less reliable time indicators, but in this case the affinities of the Spiriferoids are specific, and the ranges of Productoid genera possibly subject to revision.

Table 2

List of fossils from Carboniferous of Nepal

Species	Fossil localities F 67	F 127	F 111
Rhipidomella sp.		×	
Orthotetid		×	
?Eomarginifera sp.			×
Linoproductus pollex n. sp.	×		
Fusella mucronata n. sp.	×	×	
Eomartiniopsis cf. *helenae* SOKOLŠKAJA	×		
Punctospirifer sp.		×	
Syringothyris curzoni glaber n. subsp.	×	×	

Table 3

Details of fossil localities from Nepal

Collection Number	Description
	Carboniferous
127	Uppermost 25 *m.* of the dark limestone which is in the main Carboniferous, N. of Barbong, Barbung Khola.
67, 111	Highest beds of the dark limestone formation, transition into the Permian Quartzite-Sandstone-Shale formation; about 4 *km.* N. of Barbong. Barbung Khola.
	Permian
58	In 5 *m.* of sandstone, 25—30 *m.* above the limestone of F 57 *) or out of the lower third of the Quartzite-Sandstone formation. West side of Tarap Khola, S. of Tarap.
105	At the foot of the steep East faces of the mountains W of Tukot, Barbung Khola. The horizon is not certain but the matrix suggests the Quartzite-Sandstone formation.

*) F 57 is a Carboniferous locality 1 *mm.* below the Permian quartzites. No fossils have been described from it in this report.

94 A limestone layer of the upper shaly part of the Quartzite-Sandstone formation. Upper course of the valley ENE of Terang, Babung Khola.

129 Limestone layers of upper part (?) of Permian. NE of Charka (Barbung Khola).

130 From shaly limestone of upper part of Permian, NE of Charka, N of No. 129.

147 Approximately from the same horizon. SW of Dingju, Langu Valley.

148 Sarung Khola about 10 *km.* SSW of Dingju. In this northwestern part of the mapped area, the Carboniferous limestone is missing and typical Permian Quartzite series is replaced by soft arenaceous shales with a single fossil.

117 Arenaceous shales of the pper part of the Quartzite-Sandstone formation, from the ridge SW of the Tekochen Banjang between Babung Khola and Tarap.

112 A layer of dark limestone of the upper beds of the Permian (15 *m.* below the Lower Triassic), 7 *km.* N of Babung Khola.

113 Believed to belong to the same horizon as 112, a little N of No. 112.

108 Uppermost horizon of the Permian at base of limestone bed 1.5 *m.* thick that contains a Lower Triassic fauna in its upper part. There is about 1 *m.* of unfossiliferous limestone between the Triassic and the Permian faunas.

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Plate 1

Figs. 1, 4: *Orthotetes bisulcatus* n. sp. 1, holotype, ventral valve; 2. dorsal valve Both specimes from F 112, ×2.

Figs. 2, 3: *Multispinula indica* (WAAGEN). 2, rubber latex cast of spines over the umbo, ×4; 3, internal mould of ventral valve ×2. Both from F 112.

Fig. 5: *Spiriferella rajah* (SALTER), ventral valve from F 117, ×1.

Fig. 6: *?Neochonetes* sp. indet., dorsal valve from F 108, ×1.

Most specimens are distorted. They have been generally mounted with the hinge axis parallel to the top of the page.

Plate 1

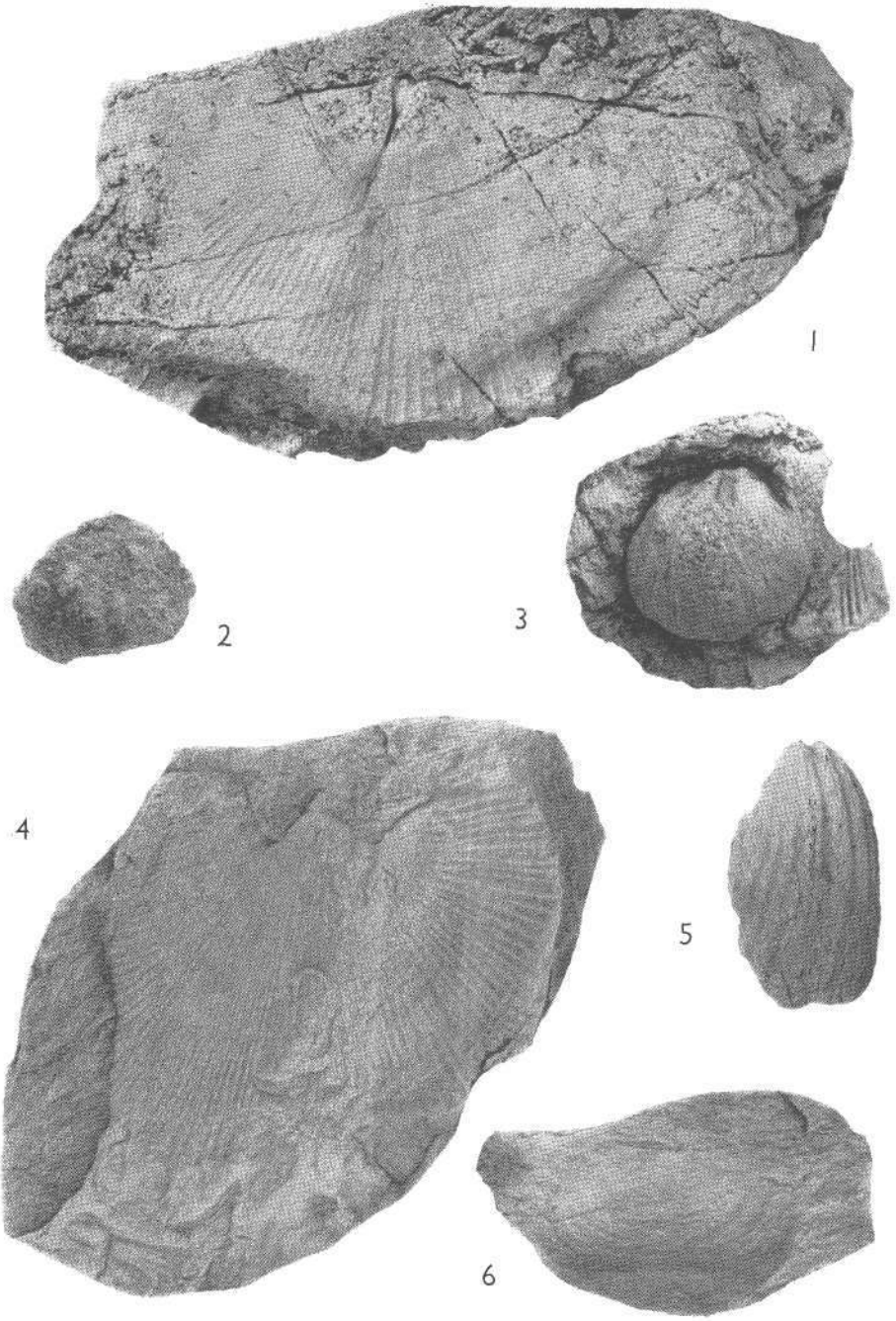
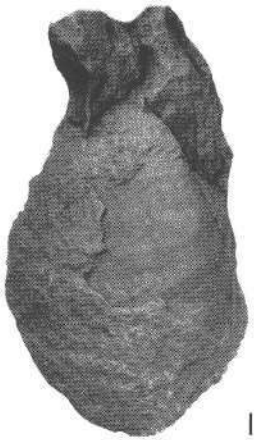


Plate 2

Figs. **1**, **5**: *Krotovia opuntia* (WAAGEN), ventral and dorsal aspects of specimen from F 112, ×2.

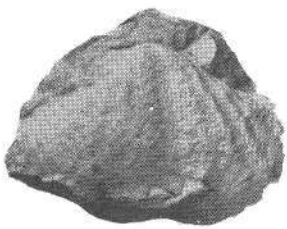
Fig. 2: *Spiriferella tibetana* (DIENER), ventral valve from F 108, ×1.

Figs. 3, 4: *Orthotetes bisulcatus* n. sp. **3**, external mould of dorsal valve; **4**, decorticated internal mould of dorsal valve, showing muscle scars. Both from F 112, ×2.



1

3



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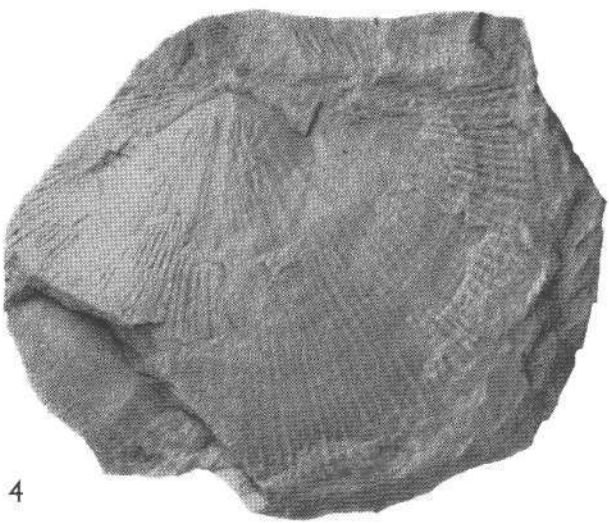


4

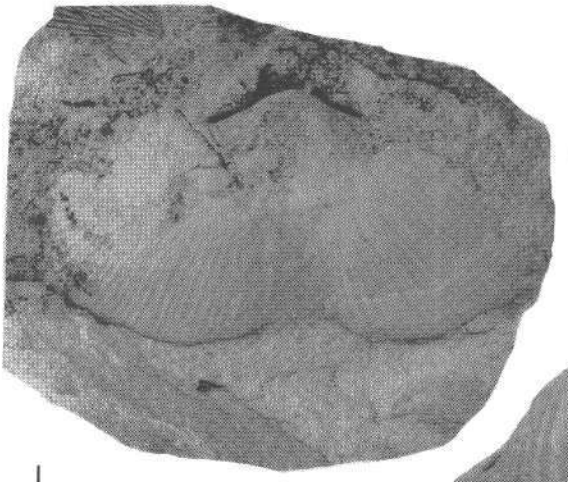
5

Plate 3

Fig. 1: *Orthotetes bisulcatus* n. sp., internal mould of dorsal valve from **F** 112, showing crural plates, ×2.

Fig. 2: *Spiriferella rajah* (SALTER), decorticated dorsal valve from **F** 58, ×1.

Figs. 3—5: *Marginifera* sp. 3, 4, anterior and disc views of external mould of dorsal valve; 5, decorticated ventral valve. Both from **F** 108, ×2.



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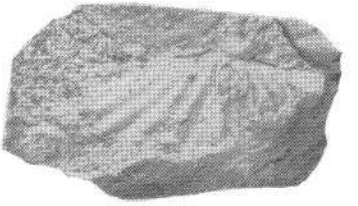

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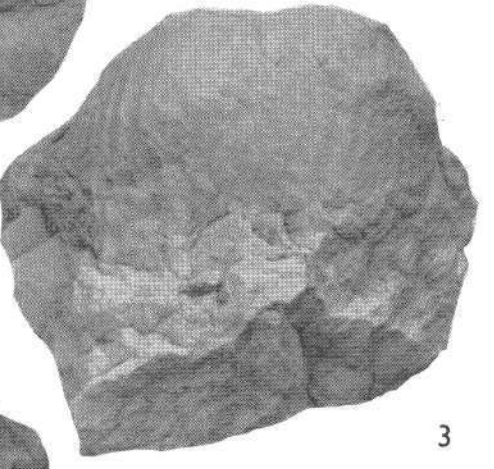

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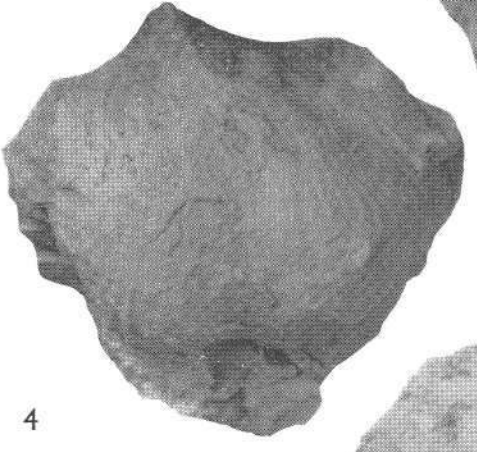

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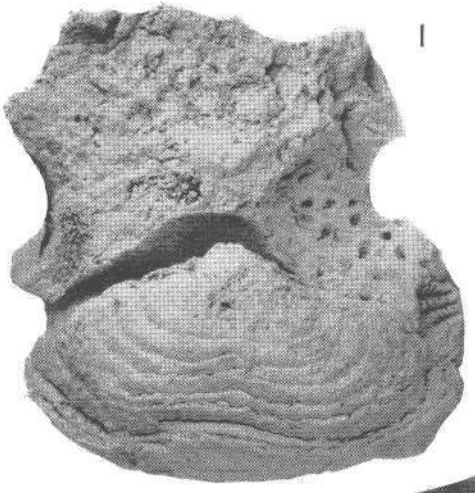
Plate 4

Figs. 1, 4, 5: *Anidanthus fusiformis* n. sp. 1, holotype, external mould of dorsal valve with umbonal and cardinal part of ventral valve, F 112, ×2.
An umbonal fragment of an external mould of a ventral valve of *Multispinula indica* (WAAGEN) lies above. 4, 5, decorticated ventral valves from F 108, ×2.

Figs. 2, 3: *Waagenoconcha purdoni* (DAVIDSON). 2, ventral valve from F 112, ×1; 3, external mould from umbonal shoulder of ventral valve from F 58, ×3 approx. Anterior surface faces bottom of page.

Fig. 6: *Linoproductus lineatus?* (WAAGEN), internal mould of ventral valve from F 105, ×1.



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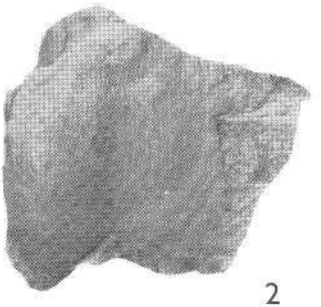

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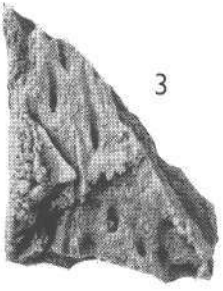

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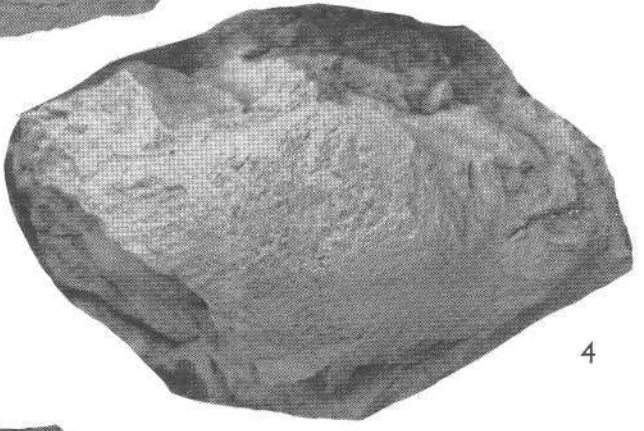

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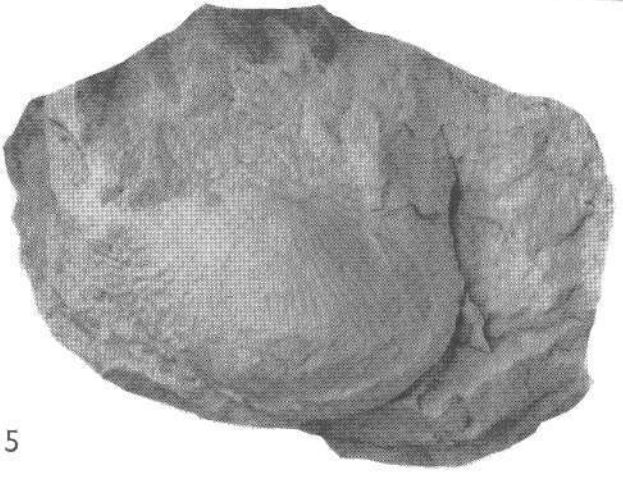

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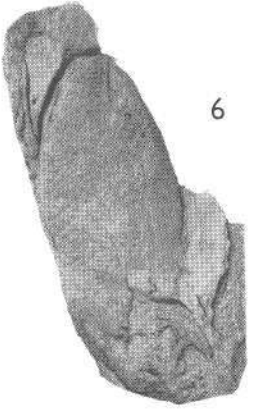

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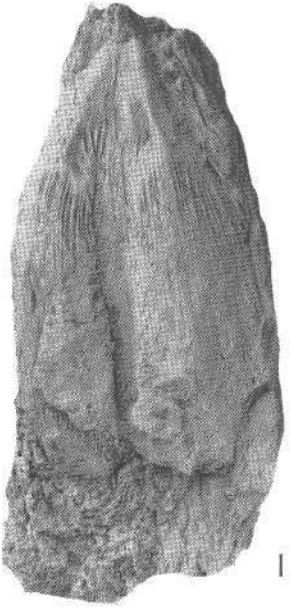
Plate 5

Figs. 1, 4, 5: *Costiferina alata* n. sp. 1, natural internal mould of distorted ventral valve showing muscle scars, ×0.75; 4, external mould of dorsal valve, with posterior face of cardinal process, ×1; 5, external mould of dorsal valve, with some shell attached, ears better preserved than in other two specimens, ×1. All from F 58.

Figs. 2, 3: *Waagenoconcha purdoni* (DAVIDSON). 2, external mould of dorsal valve, showing ornament (the spines as dark spots, or holes in the matrix but with hinge obscure); 3, internal mould of ventral valve. Both from F 58, ×1 approx.



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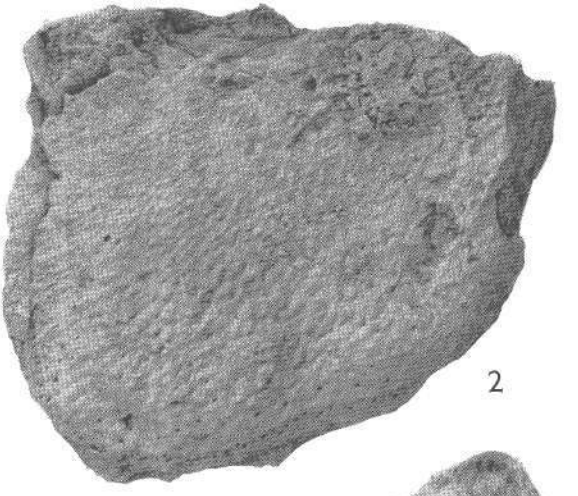

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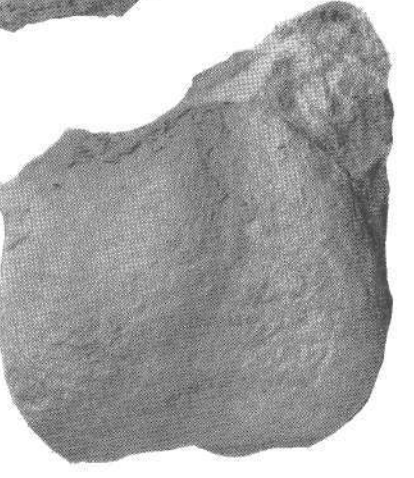

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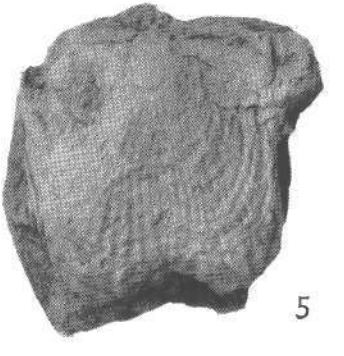

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Plate 6

Figs. 1—3: *Costifrrina alata* n. sp. 1, internal mould of ventral valve, with radial rugae visible anteriorly, ×1; 2, external mould of dorsal valve with posterior face of cardinal process and very alate cardinal extremities, ×0.75; 3, holotype, external mould of dorsal valve with umbonal part of ventral valve, ×0.75 approx. All from F 58.

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2

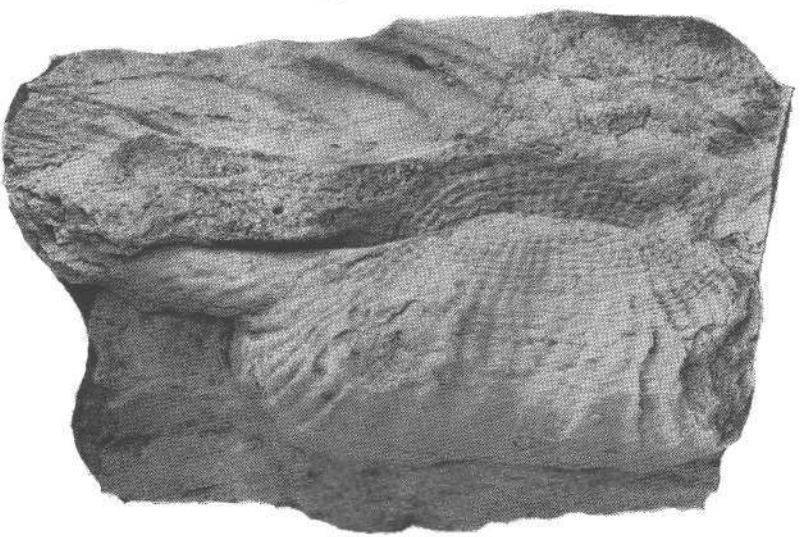

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Plate 7

Figs. 1, 2, 4: *Spiriferella rajah* (SALTER). 1, lateral view of ventral valve; 2, internal mould of ventral valve showing muscle platform and dental and adminicular plates, with a little of the external mould above; 4, internal view of ventral valve, see also pl. 11, fig. 2. All from F 117, ×1.

Figs. 3, 5: *Costiferina alata* n. sp. 3, exterior mould of dorsal valve (with the trail not visible, having been bent back and under the specimen by distortion) and ginglymus, and large ear, and internal mould of posterior part of ventral valve, showing adductor scars clearly; 5, internal mould of ventral valve. Both from F 58, ×1 approx.

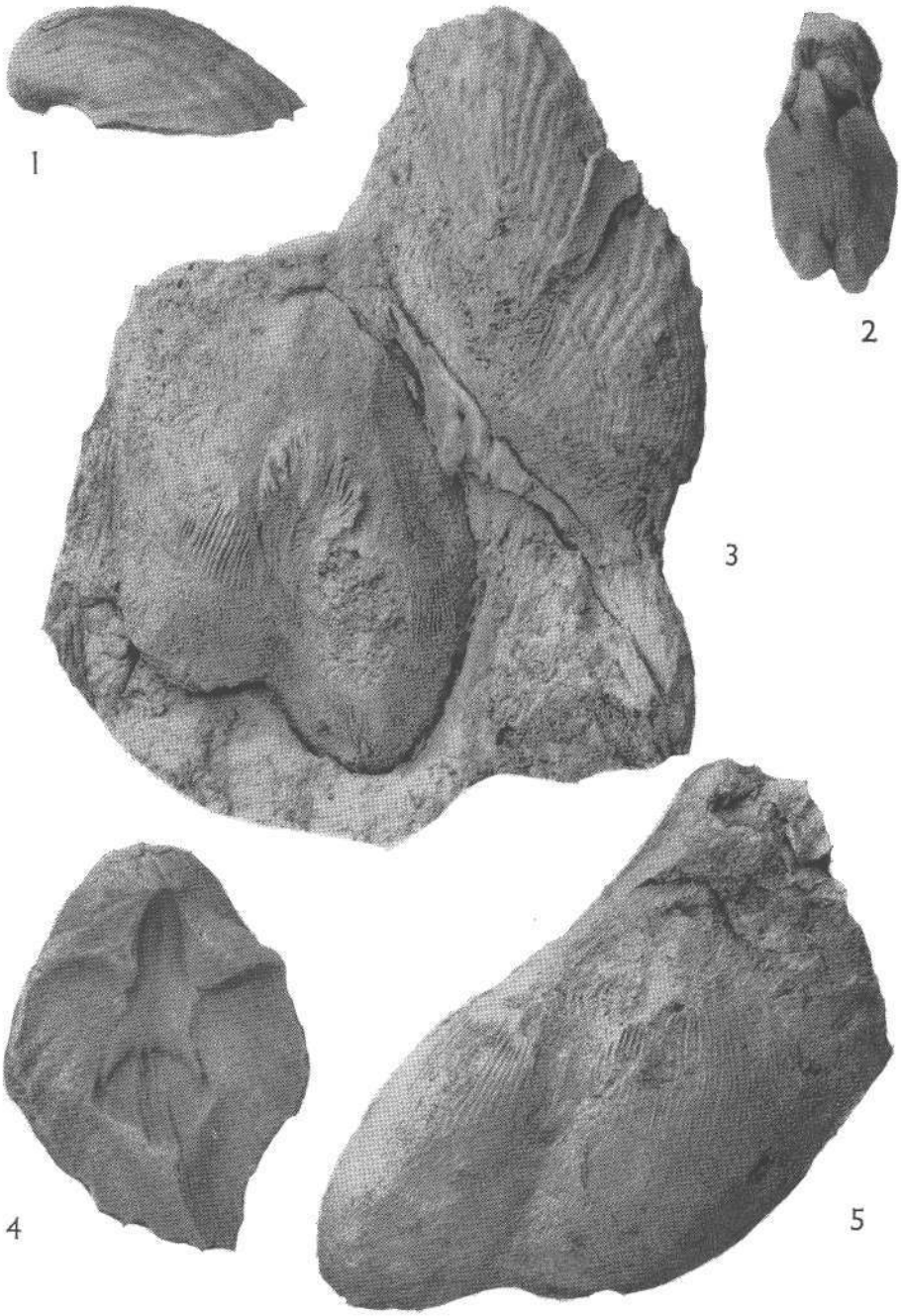
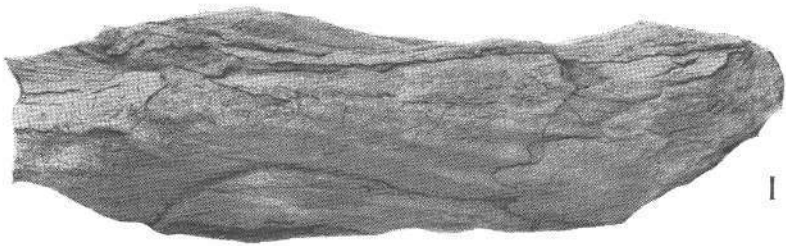


Plate 8

Figs. 1, 2: *Neospirifer moosakhailensis* (DAVIDSON). 1, stretched specimen with valves conjoined and apparently very wide sulcus from F 130, ×0.75; 2, anterior aspect with dorsal valve uppermost of gerontic specimen with valves conjoined from F 113, ×1.

Fig. 3: Dictyoclostid gen. and sp. indet. in lower middle of figure, external mould of dorsal valve. An internal mould of a ventral valve of *Cleiothyridina subexpansa* (WAAGEN) lies at upper left, with fragment of external spines along the edge of the specimen. Above the Dictyoclostid on the right is an external mould of a ventral valve of *Anidanthus fusiformis* n. sp. Ventral valves of *Multispinula indica* are represented by a fragment of the exterior between the Dictyoclostid and *Cleiothyridina*, and part of an internal mould to the lower left of the Dictyoclostid. F 112, ×2.

Fig. 4: *Costiferina alata* n. sp., exterior of dorsal valve and ginglymus, from F 58, ×1.



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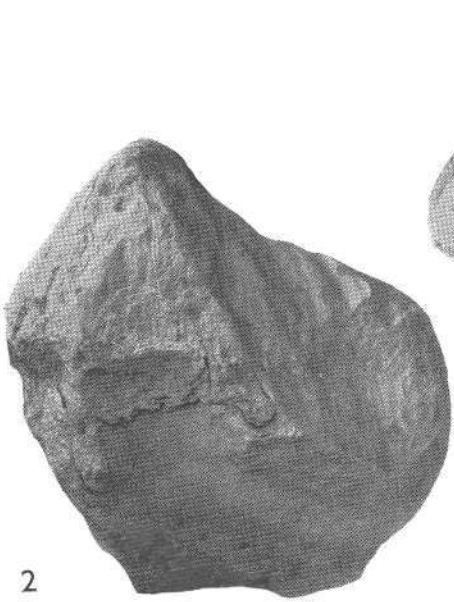

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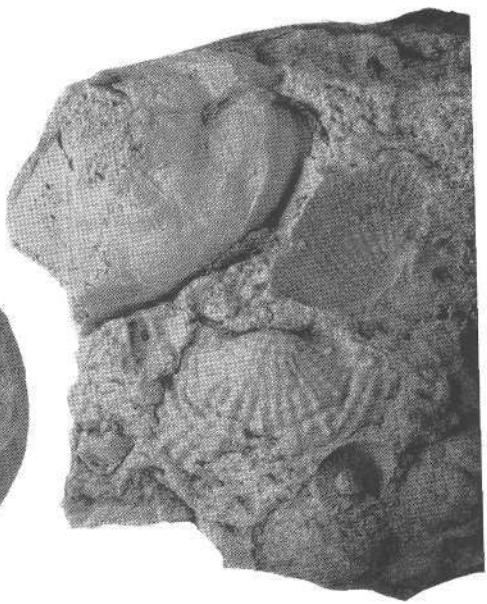

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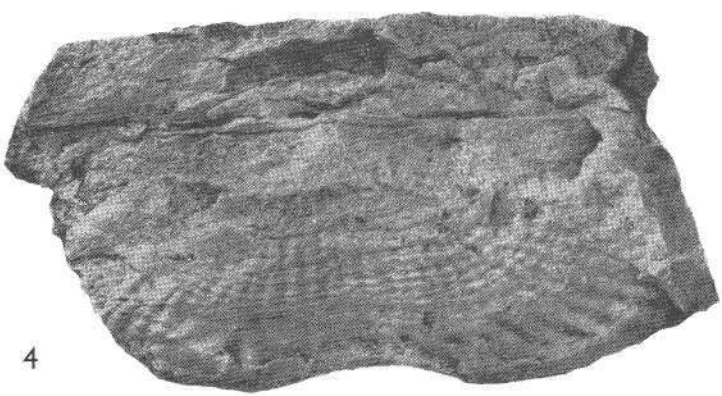

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Plate 9

Figs. 1, 4: *Neospirifer moosakhailensis* (DAVIDSON). 1, ventral valve from F 130, × 0.75 approx; 4, dorsal aspect of specimen with valves conjoined, much decorticated and partly obscured by matrix, from F 108, × 2.

Fig. 2: *N. ravana* (DIENER), internal mould of ventral valve, with some shell remaining to right of muscle platform. From F 112, × 1.

Fig. 3: *Spiriferella tibetana* (DIENER), a partly decorticated fragment of a ventral valve from F 130, × 1.

Fig. 5: *Fusispirifer nitiensis* (DIENER), internal mould and cardinal area of ventral valve from F 58, × 1.

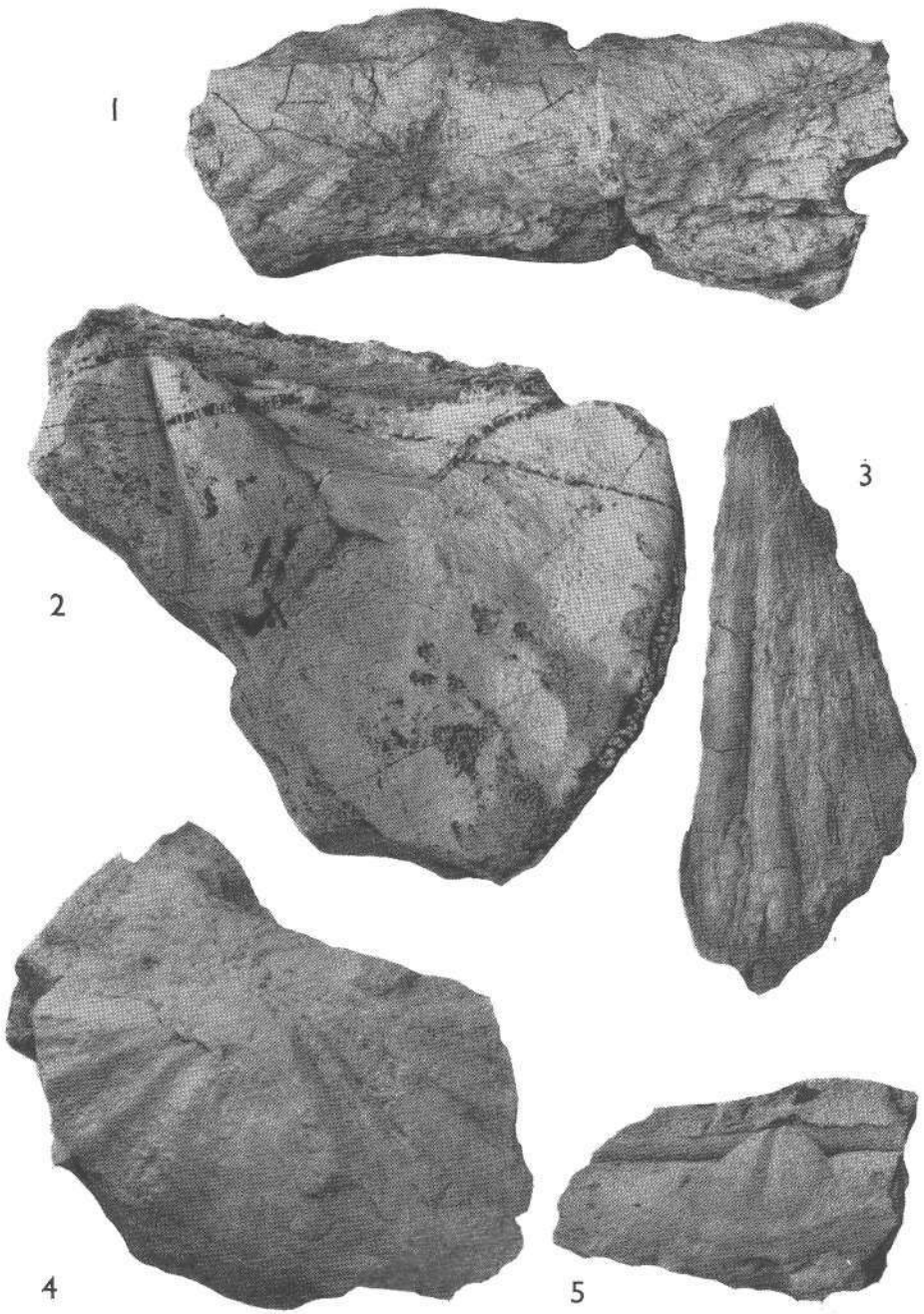
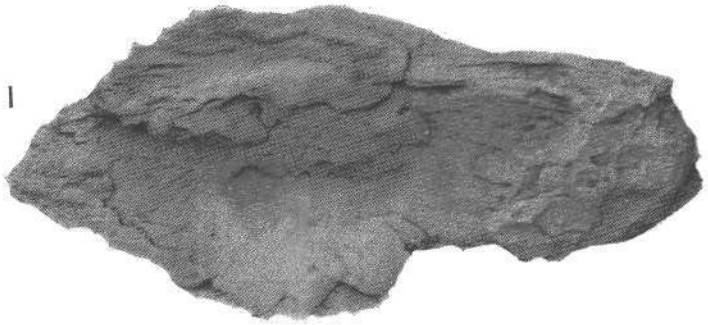


Plate 10

Figs. 1, 2: *Neospirifer moosakhailensis* (DAVIDSON). 1, interior of ventral valve, with posterior part of dorsal valve, from F 130, ×1; 2, ventral valve from F 148, ×1.

Fig. 3: *Cleiothyridina subexpansa* (WAAGEN), internal mould of dorsal valve from F 108, ×1.

Fig. 4: *Neospirifer ravana* (DIENER), dorsal aspect of large specimen with valves conjoined from F 112, ×0.75 approx.



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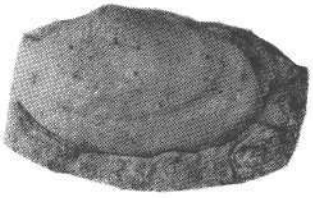

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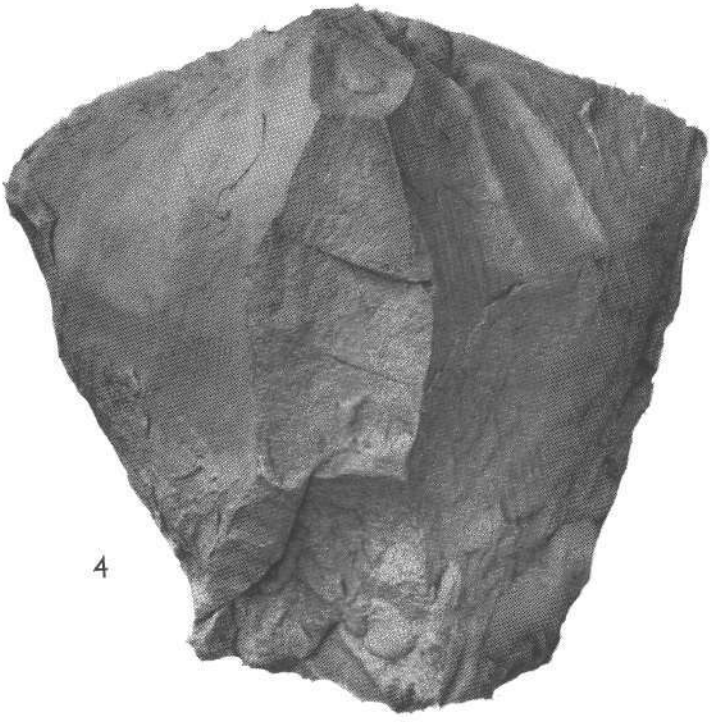

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Plate 11

Figs. 1, 3, 4: *Fusispirifer nitiensis* (DIENER). 1, internal mould of ventral valve with interarea from F 58, ×1; 3, 4, ventral and dorsal views of large decorticated specimen, the median mass of fig. 3 being the muscle platform. From F 113, ×0.66.

Fig. 2: *Spiriferella rajah* (SALTER), ventral valve from F 117, ×1.

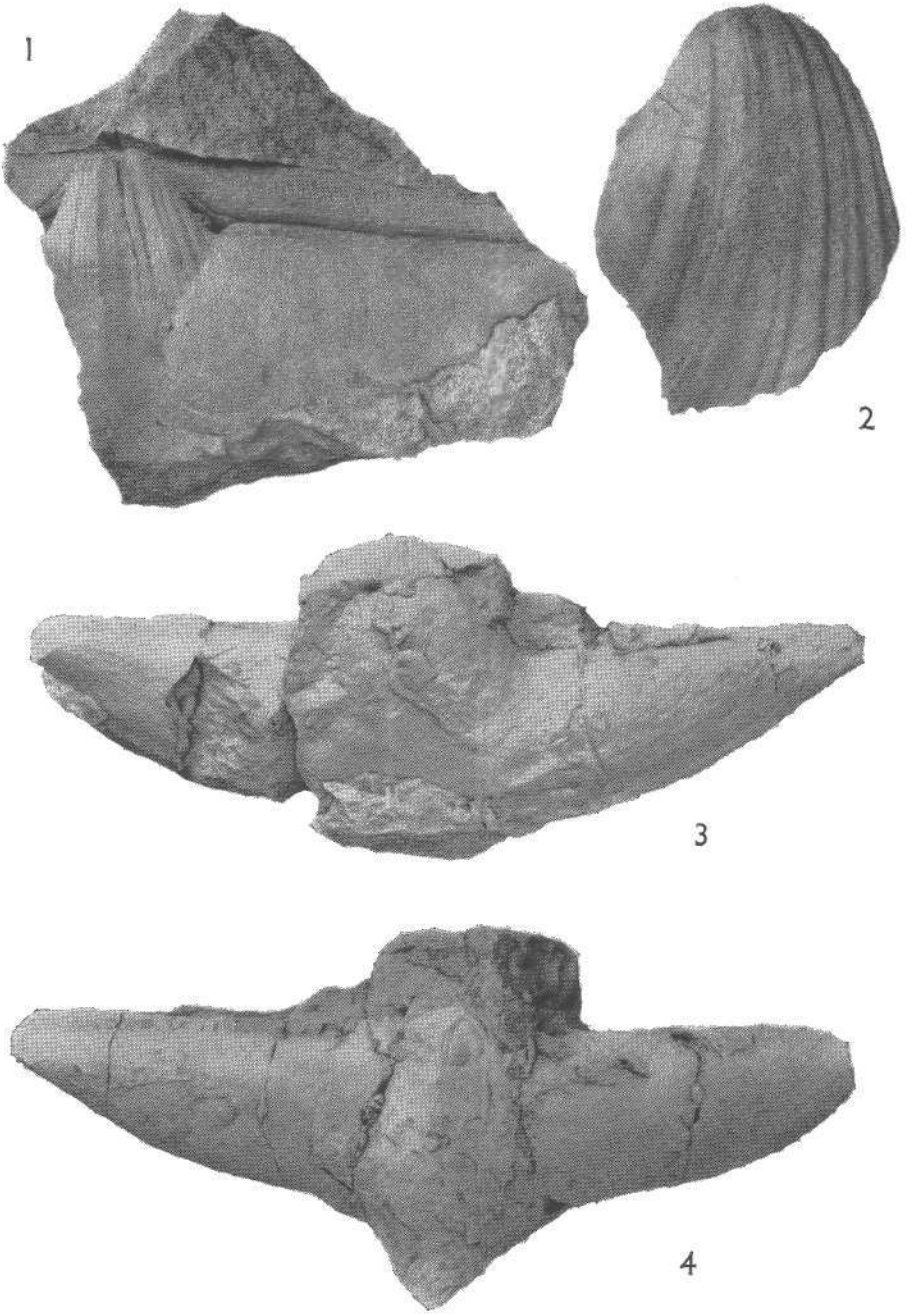


Plate 12

Fig. 1: *Fusispirifer nitiensis* (DIENER), ventral valve partly decorticated, from F 58, ×0.9 approx.

Fig. 2: *Spiriferella rajah* (SALTER), ventral valve with angular cardinal extremity, from F 117, ×1.

Figs. 3, 4: *S. tibetana* (DIENER). 3, transverse ventral valve, ×1; 4, elongate ventral valve, ×2. Both from F 108.

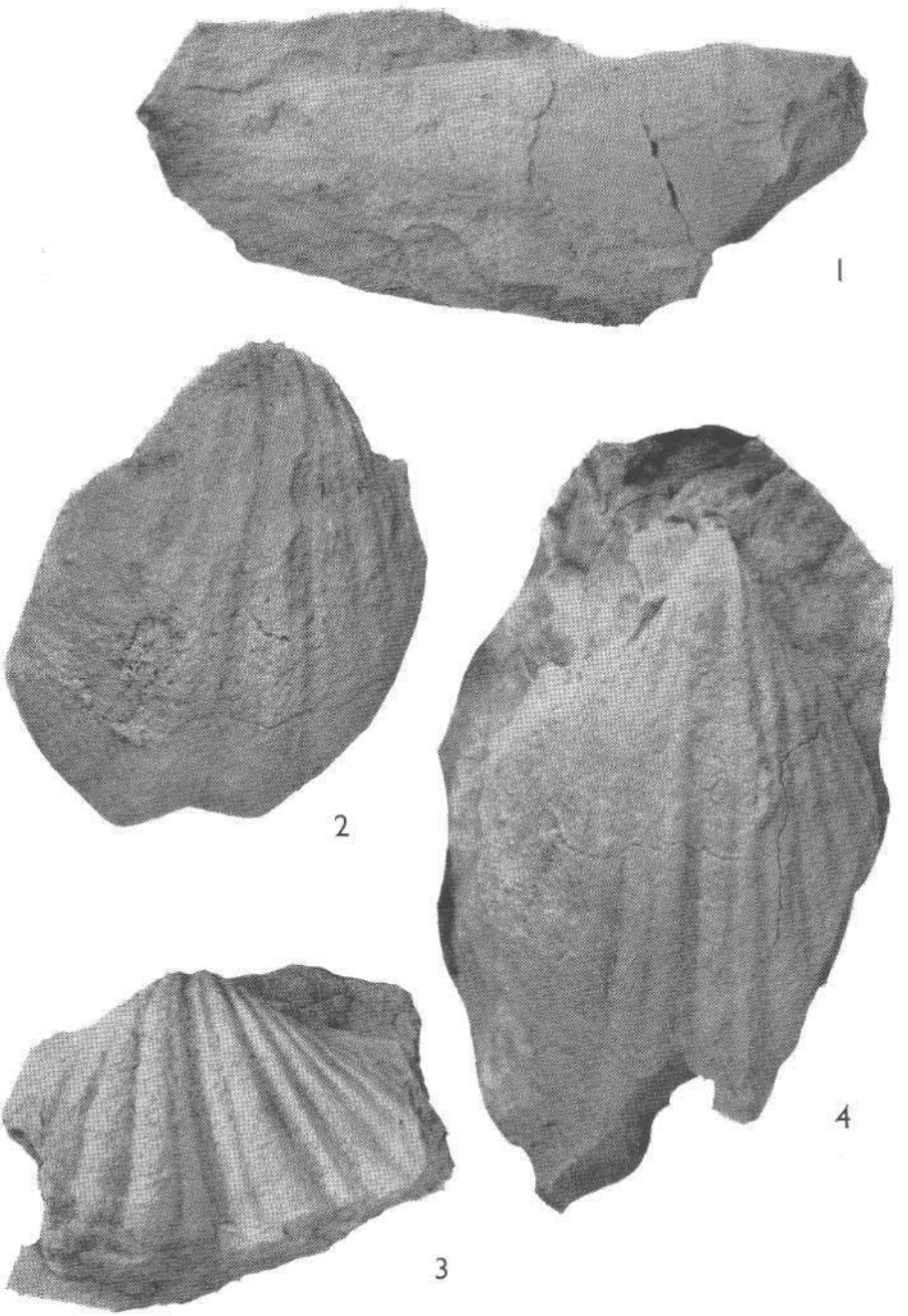


Plate 13

Figs. 1, 2, 4, 5: *Spiriferella tibetana* (DIENER). 1, 5, ventral and damaged dorsal valves from F 130, squashed and broken, × 1; 2, 4, ventral valves from F 108, × 1.

Fig. 3: *Syringothyris lyddekeri ?* (DIENER), distorted and worn ventral valve from F 105, × 1.

Fig. 6: *Punctospirifer* sp., decorticated dorsal valve from F 108, × 1.

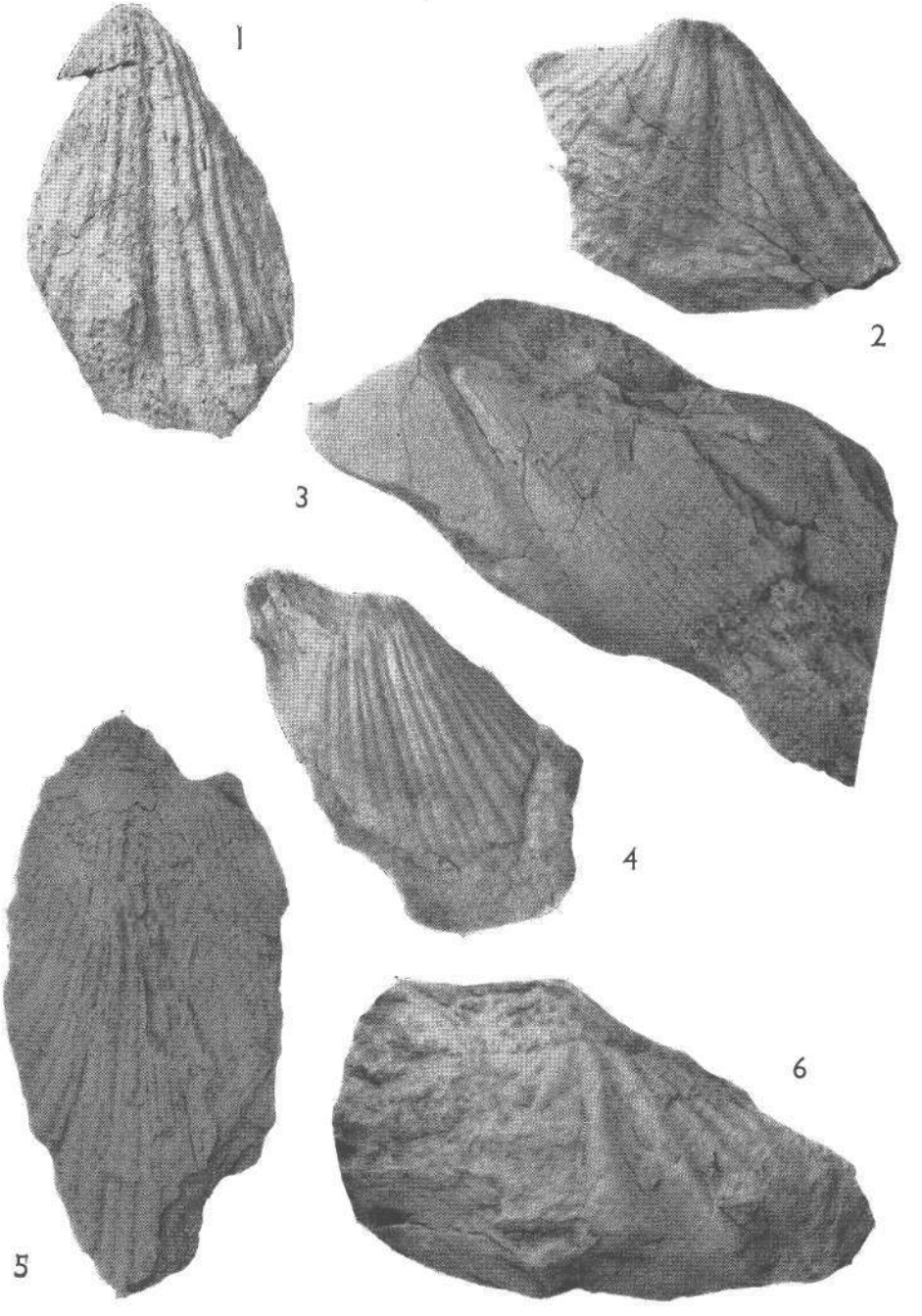
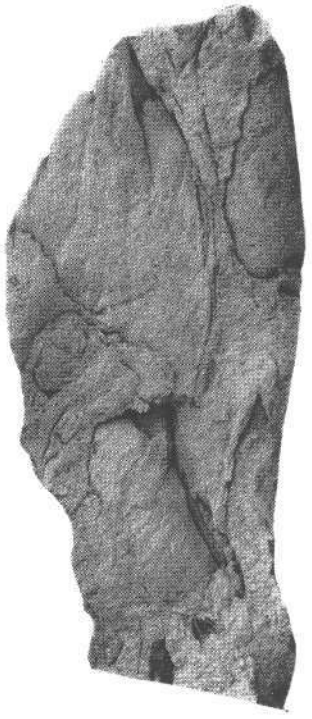


Plate 14

Fig. 1: *?Hoskingia latouchei* (DIENER) and *Martiniopsis* sp., ventral aspects of internal moulds from F 105, × 1.

Figs. 2, 3, 5, 6: *Rhipidomella* sp. 2, 5, ventral and dorsal aspects of a small specimen (subsequently destroyed by acid leaching), × 1; 3, internal mould of dorsal valve, × 2; 6, ventral valve, decorticated, × 2. All from F 127.

Fig. 4: *Eomarginifera* sp., distorted, partly decorticated ventral valve. See also pl. 15, fig. 2. From F 111, × 1.



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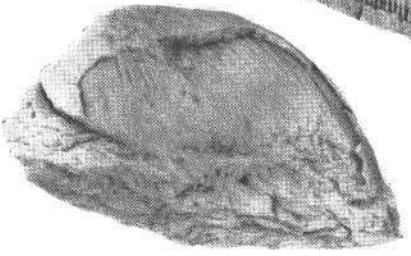

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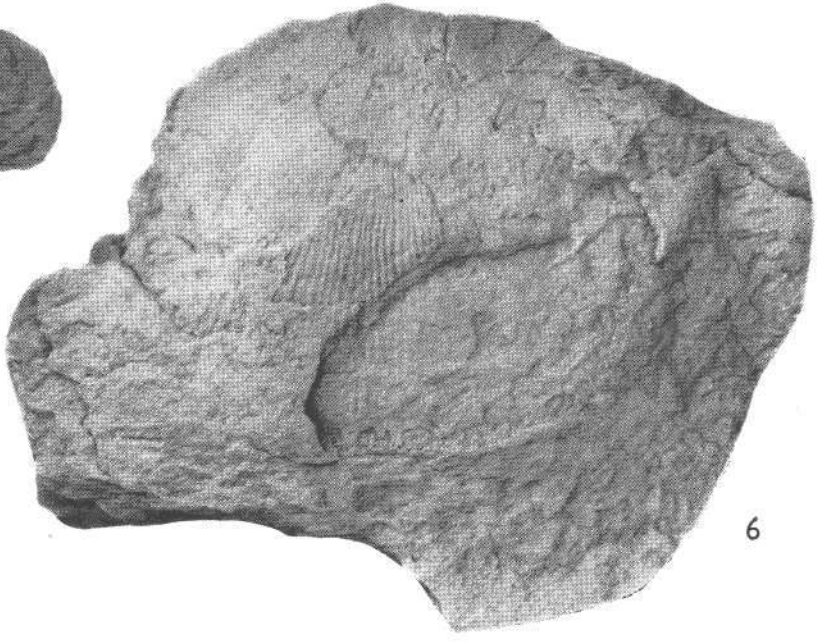

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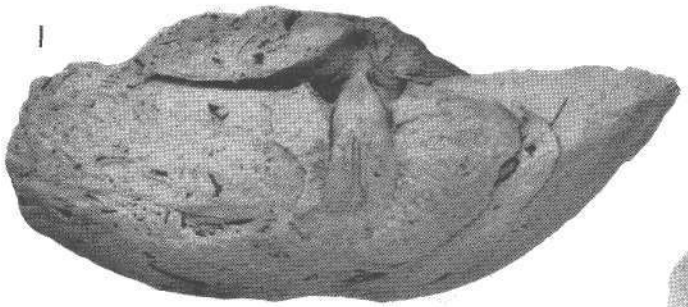
Plate 15

Fig. 1: *Fusella mucronata* n. sp., internal mould of ventral valve from F 127, ×2. See also pl. 16, fig. 4.

Fig. 2: *Eomarginifera* sp., posterior aspect of ventral valve from F 111, ×1.

Figs. 3, 5: *Linoproductus pollex* n. sp. 3, holotype, anterior aspect of specimen before leaching in acid, showing decorticated ventral valve posteriorly, disc, and the external surface of the dorsal valve anteriorly; 5, more posterior view of holotype after leaching, showing ventral muscle scars, and exterior of dorsal valve under the visceral disc. From F 67, ×1.

Figs. 4, 6: *Rhipidomella* sp. 4, ventral aspect of specimen with valves conjoined before leaching in acid; 6, same specimen after leaching, showing external mould of dorsal valve. The large and small tubules of matrix, representing pores through the shell, are visible in the bottom left corner.



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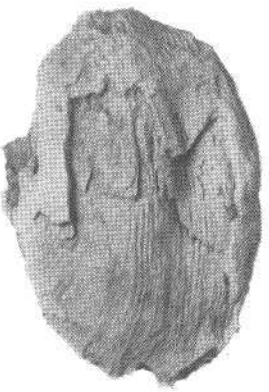

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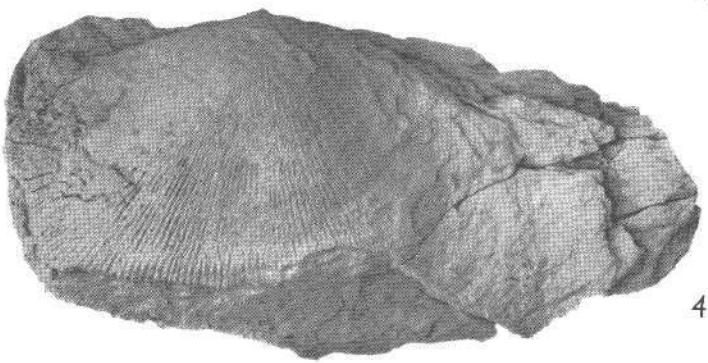

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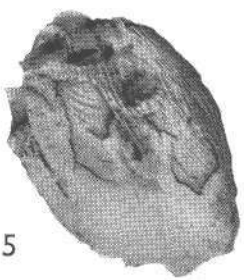

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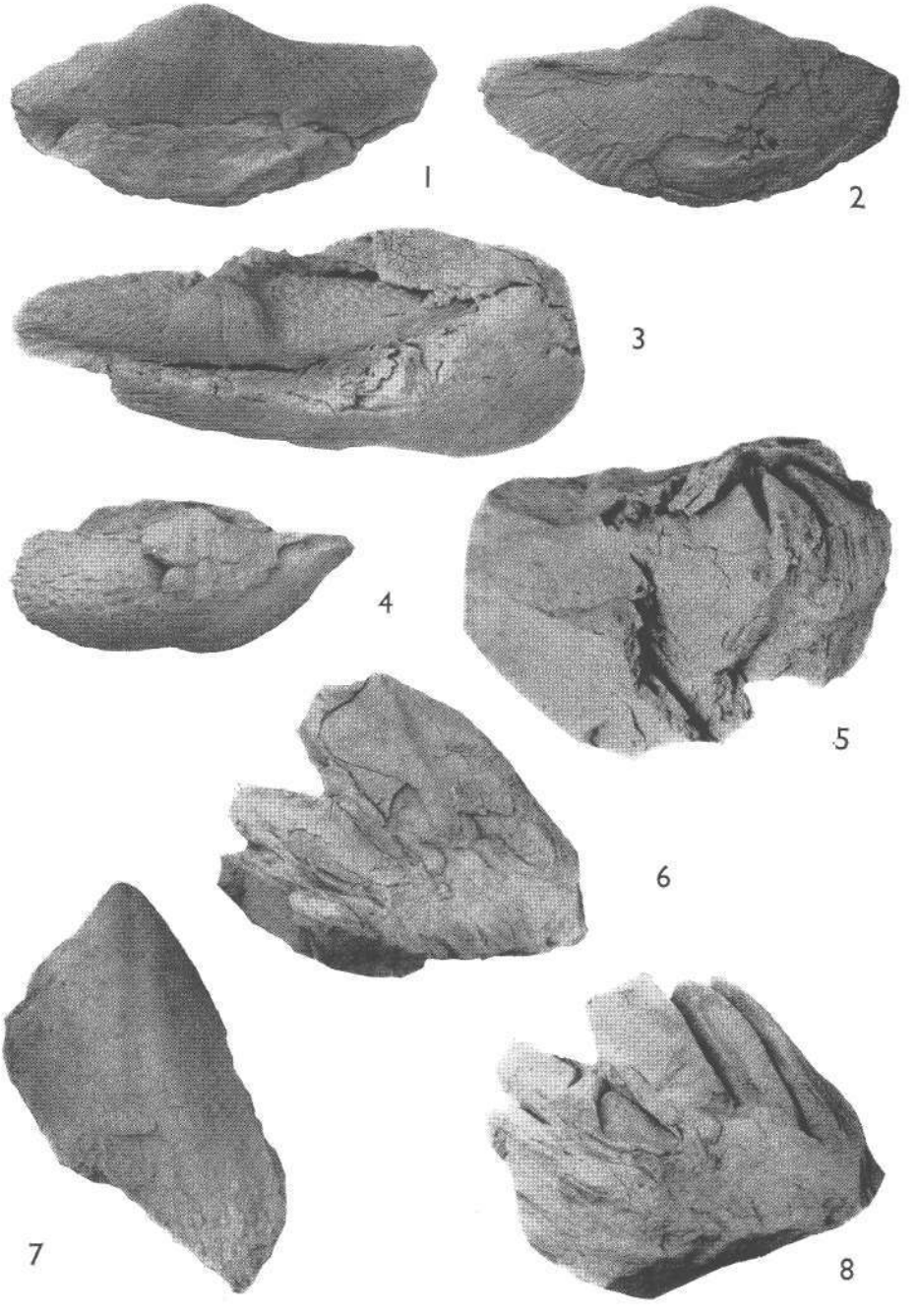
Plate 16

Figs. 1—4, 7: *Fusella mucronata* n. sp. 1, 2, ventral and dorsal aspects of holotype, with growth lines on left side of dorsal valve indicating mucronate cardinal extremities. From F 127, ×1; 3, internal mould of ventral valve, probably more mature than that of pl. 15, fig. 1. From F 67, ×2; 4, damaged ventral valve with a little umbonal shell, see also pl. 15, fig. 1. From F 127, ×1. 6, 8, umbonal fragment of ventral valve, external and internal, to left of *Syringothyris*, from F 67, ×1.

Fig. 5: *Eomartiniopsis* cf *helenae* SOKOLSKAJA, internal mould of distorted ventral valve from F 67, ×1.

Figs. 6—8: *Syringothyris curzoni glaber* n. subsp. 6, 8, ventral valve before and after leaching in acid, to right of *Fusella;* 7, holotype ventral valve. Both from F 67, ×1.



Index of species and genera

(For the systematic descriptions only the first page reference is recorded, and further references in the particular description are likely to follow.) Subgenera are treated as genera, and the correct generic identification is given in brackets.