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Permian bivalves from West Spitsbergen, Svalbard Islands, Norway

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Abstract. The bivalve fossils collected by Japanese-Norwegian research groups from the Kapp Starostin Formation in west Spitsbergen are described. They comprise fourteen species belonging to the Pterioida and two species of the Arcoida. Among them, six species, including two that are indeterminate, are newly described. They are *Grammatodon* (*Cosmetodon*)? *suzukii, G.* (*C.*)? sp. ind., *Streblochondria winsnesi, Vorkutopecten svalbardensis, Deltopecten* sp. ind., and *Palaeolima nakamurai*. The fauna belongs to the Boreal bioprovince, but a single species, *Cassianoides sexcostatus* (Stuckenberg) has also been reported from the Central Rocky Mountains of the United States. The bivalve fauna suggests an Artinskian-Kungurian age for the Kapp Starostin Formation. This is somewhat earlier than the age deduced from brachiopods and bryozoans, but it is not decisive because the materials are poor. The Kapp Starostin Formation is conformably overlain by the *Otoceras*-bearing, earliest Triassic Vardebukta Formation, so a time-gap corresponding at least to the Dorashamian and Dzhulfian (=Tatarian) is inferred between the two formations.

Key words: Kapp Starostin Formation, Permian bivalves, Spitsbergen

Introduction

The study materials were collected by Nakamura *et al.* in 1984 and 1990, and by Nakazawa *et al.* in 1986 from the Permian Kapp Starostin Formation of west Spitsbergen, in the Svalbard Islands, Norway. Brachiopods and bryozoans are most abundant among the macrofossils. Many species of brachiopods have been described by various authors, notably, Frebold (1937) and Gobbet (1963). Bivalves are found rather rarely and the descriptive studies are few. Toula (1873, 1875a, b) first described the following species, collected from "Carboniferous-Permian" strata on Sørkapp Island off the southerntip of Spitsbergen, and Axel Island in Bellsund and on Hornsund, on the west coast of Spitsbergen:

Pecten (*Aviculopecten*) *bouei* Verneuil, *Pecten* (*Aviculopecten*) *kokscharofi* Verneuil, *Pecten* (*Aviculopecten*) cf. *ellipticus* Phillips, *Pecten* (*Aviculopecten*) cf. *dissimilis* Fleming, *Pecten* (*Aviculopecten*) *wilczeki* Toula, *Gervillia* cf. *antiqua* Münster, *Aviculopecten draschei* Toula and *Gervillia* sp.

Frebold (1937) described the following species, mostly from the upper part of the Kapp Starostin Formation in the Festningen section, located on the southern coast of Spitsbergen at the entrance to Isfjorden and from Sørkapp Island:

Aviculopecten (*Deltopecten*) cf. *mutabilis* Licharew and *A.* (*D.*) cf. *hiemalis* Salter, *Aviculopecten*? sp. indet., *Pecten* (*Aequipecten*)? *keyserlingiformis* Licharew, *Pecten* (*Aequipecten*) *keyserlingi* Stuckenberg, *Pecten* (*Pseudamusium*) cf. *ufaensis* Tschernyschew, *Pecten* (*Pseudamusium*) ex aff. *sericeus* Verneuil, *Parallelodon* sp. ind., genus [=*Parallelodon*?] et sp. ind., *Clidophorus*? sp. ind., *Pecten wilczeki* Toula, and *Leda* sp. ind.

Among the species described by Toula, *Aviculopecten bouei* was referred to *Aviculopecten* (*Deltopecten*) *mutabilis* by Licharew (1927). *Pecten* cf. *ellipticus* was identified as *Pecten* (*Pseudamusium*) ex aff. *sericeus* Verneuil, and *Pecten* (*Aviculopecten*) cf. *dissimilis* was compared to *Aviculopecten netschajewi* Licharew and reported as *Aviculopecten*? sp. ind. by Frebold (1937). *Aviculopecten kokscharofi* reported by Toula (1873) is probably identical with *Aviculopecten* cf. *hiemalis* illustrated by Licharew (1927, especially pl. 5, fig. 20), and is referred to *Etheripecten* cf. *mutabilis* Licharew in the present paper.

Among the species reported by Frebold, *Aequipecten keyserlingi* was considered to belong to the genus *Morrispecten* Muromtseva and Guskov by Muromtseva (1984, p. 75). *Morrispecten* is, however, a junior synonym of *Undopecten* Waterhouse, 1982 (Newell and Boyd, 1995). *Pecten* (*Aequipecten*)? *keyserlingiformis* and *Aviculopecten* (*Deltopecten*) cf. *mutabilis* and *A.* (*D.*) cf. *hiemalis* of Frebold are referred to *Etheripecten keyserlingiformis* and *E.* cf. *mutabilis*?, respectively. *Pseudamusium* cf. *ufaensis* and *Parallelodon* sp. ind. are identified as *Streblochondria winsnesi* sp. nov. and *Grammatodon* (*Cosmetodon*) ? *suzukii* sp.

nov., respectively, in the present paper. Sixteen species including four new species and two indeterminable ones are described. All the materials are kept at the Department of Geology and Mineralogy, Faculty of Science, Kyoto University.

Stratigraphy

The fossils were collected at four localities in west Spitsbergen, namely, the Festningen section along the southern coast of the entrance to Isfjorden, the Skansbukta section at Billfjorden, and the Reinodden and Ahlstrandodden sections along the southern coast near the entrance of Van Keulenfjorden, in Bellsund (Figure 1). Faunas from the first and second localities were collected on Nakamura's expedition in 1984 and in 1990. The stratigraphy of these sections was published by Nakamura *et al.* in 1990 and, in more detail, by the Japanese-Norwegian Research Group (1992). The other two localities were examined by Nakazawa's party in 1986 and the results were published by Nakazawa *et al.* (1990). All the materials are from the Permian Kapp Starostin Formation which was defined by Cutbill and Challinor (1965). The formation corresponds to the Brachiopod Cherts (including the *Spirifer* Limestone at the base) of previous authors (e.g., Gee *et al.*, 1953). At the type locality, Festningen, the formation is divided into three members, the Vøringen, Svenskeegga, and Hovtinden Members in ascending order (Cutbill and Challinor, 1965).

(1) *Festningen section* (Figure 2A)

At Festningen the Kapp Starostin Formation is 385 m in thickness and divided into twelve units (Nakamura *et al.*, 1990 ; Japanese-Norwegian Research Group, 1992). Unit 1, about 20 m thick, is represented by brachiopod-rich, bioclastic limestone beds corresponding to the Vøringen Member. Units 2 to 5, about 140 m thick, constitute the Svenskeegga Member, each represented mainly by siliceous shale, spicularite, spicularite and shale, and bioclastic limestone, respectively.

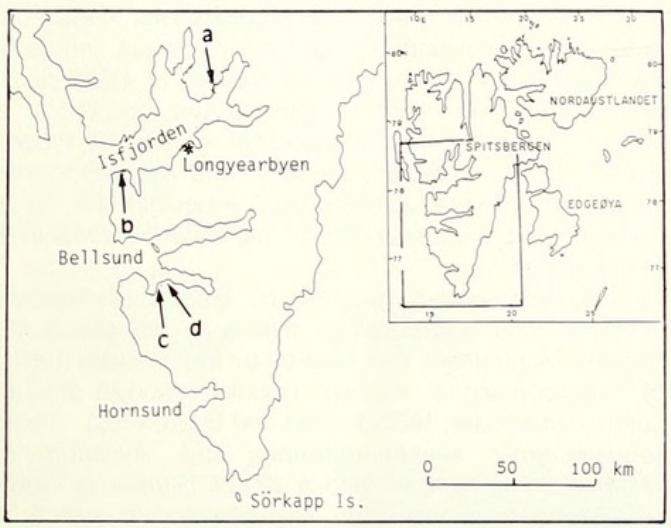

Figure 1. Map of southern Spitsbergen showing fossil localities. a : Skansbukta, b : Festningen, c : Reinodden, d : Ahlstrandodden.

The Hovtinden Member, about 225 m thick, consists of seven units, 6 to 12, each composed mainly of spicularite, alternation of spicularite and spicularitic shale, bioclastic limestone, spicularite, bioclastic limestone (partly silicified), alternation of siltstone and paper shales, and quartzose sandy shale or siltstone, respectively, in ascending order. Bivalve fossils have been obtained from Units 5, 7, 8, 9 and 11.

(2) *Reinodden section* (Figure 2B)

At Reinodden the formation reaches more than 300 m in thickness. It is classified into eight units, A to H, in ascending order (Nakazawa *et al.*, 1990). Unit A, less than 5 m thick, is the Vøringen Member consisting of fossiliferous bioclastic limestone. Units B and C are referred to the Svenskeegga Member. Unit B, about 40 m thick, is subdivided into three beds or subunits, 2 to 4. Beds 2 and 4 are represented by nodular or irregularly bedded, alternating spicularitic chert and thin mudstone. Bed 3 consists of black laminated shale and siltstone. Unit C, about 80 m thick, includes bedded black shale (Bed 5), and alternations of calcareous sandstone and limestone (Beds 6 and 7).

The Hovtinden Member (Units D to H), about 180 m thick, is characterized by coarse-grained sandstone and spicularite. It is subdivided into fourteen beds, Beds 8 to 21, as shown in Figure 2B. Glauconite is commonly found in the sandstones. Macrofossils have been collected from ten horizons (RP 1~10) in the Kapp Starostin Formation, among which RP 3, 7 and 9 contain bivalve fossils.

(3) *Ahlstrandodden section* (Figure 2C)

At Ahlstrandodden the formation is about 250 m thick. It is divided into eight units, 1 to 8 (Nakazawa *et al.*, 1990). Unit 1, 7.6 m thick, consists of brachiopod-rich bioclastic wackestone of the Vøringen Member. Units 2 and 3, which are 40 m and 58 m thick, respectively, are correlated to the Svenskeegga Member. Units 4 to 8, about 140 m thick altogether, correspond to the Hovtinden Member. They are composed mainly of spicularitic chert or spicularite, siliceous shale and a minor amount of limestone. Glauconite grains are commonly found in siliceous sandstones throughout the Hovtinden Member.

Among nine fossiliferous horizons (AP 1~9) within the formation, five horizons, AP 1, 2, 6, 7 and 8, yield bivalve shells. The fossiliferous horizons AP 8 and 9 of the upper part of the Hovtinden Member can be correlated with horizons RP 9 and 10 in the Reinodden section. They are considered to correspond to horizon F 8 of the Festningen section.

Fossil occurrence and age assignment

Sixteen species in nine genera are identified from three sections mentioned above, plus one species, *Acanthopecten licharewi* (Fredericks), from Skansbukta (SA 7), as shown in Figures 3. The localities and stratigraphic horizons are shown in Figure 2.

Nakamura *et al.* (1987, 1992) distinguished five brachiopod assemblage zones in the Kapp Starostin Formation of the Isfjorden area. They compared these faunas to those of Russia, Arctic Canada, Greenland, and Alaska, all belonging

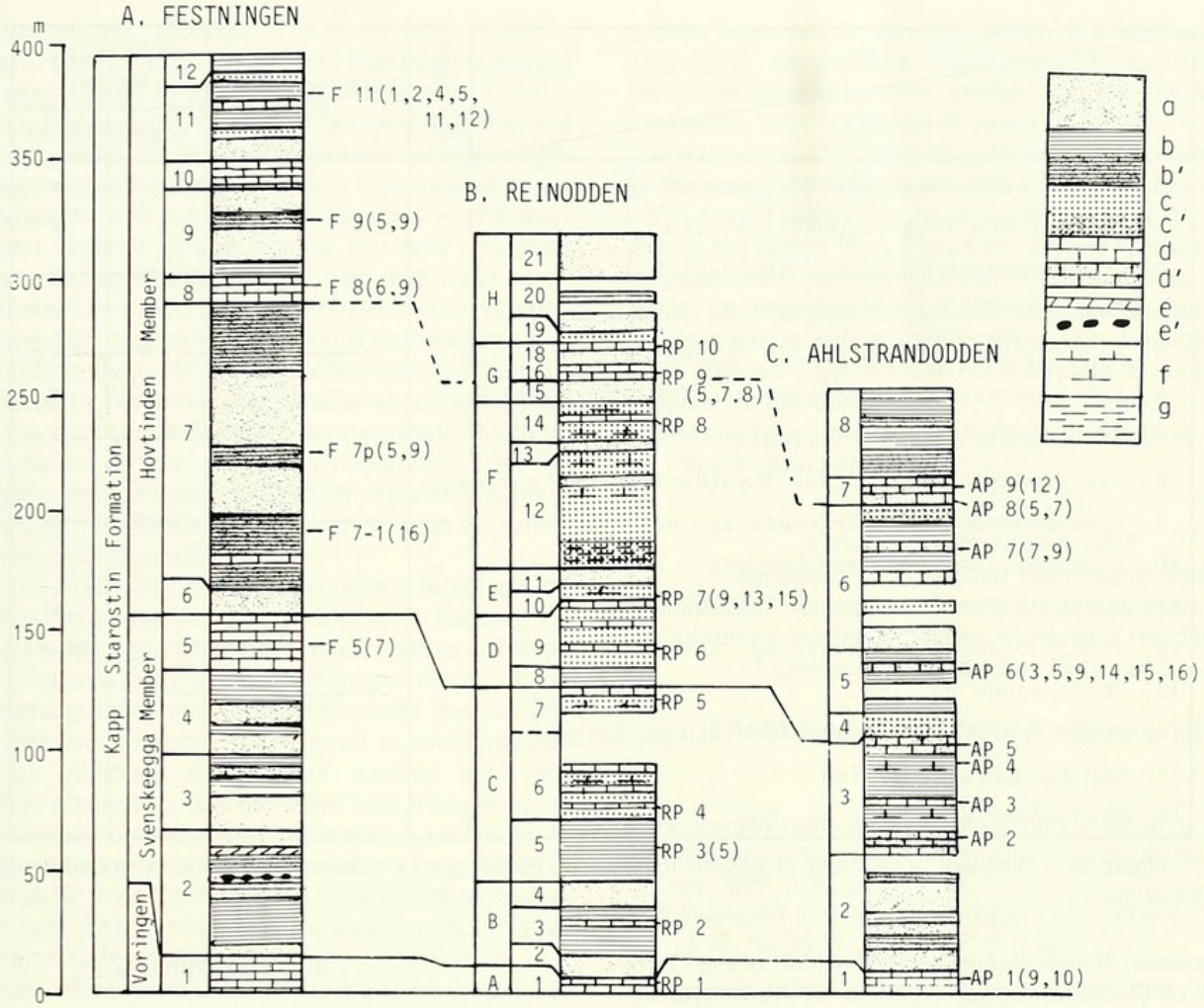

Figure 2. Geological columnar sections of the Kapp Starostin Formation at three localities showing horizons of macrofossils. a : chert or spicularite, b : shale or mudstone, b′ : siliceous or spicularitic, c : sandstone, c′ : siliceous, d : limestone, d′ : siliceous, e : dolostone, e′ : dolostone nodule, f : calcareous, g : muddy. Numbers in parentheses correspond to those of bivalve species in Figure 3. A : simplified from Japanese-Norwegian Research Group (1992, fig. 2), B and C : from Nakazawa *et al.* (1990, fig. 2).

to the Boreal bioprovince. From the correlation of these faunas, they concluded that the Kapp Starostin Formation ranges in age from Kungurian up to Midian or early Dzhulfian (Tatarian). Sakagami (1992) studied the bryozoans and pointed out the similarity of the fauna from the Vøringen Member with the Kungurian fauna in the Timan-Pechora region. Faunas of the Svenskeegga and Hovtinden Members resemble Ufimian faunas of Arctic Canada and the Russian Far East, the Kazanian fauna of the southern Urals, and the Late Permian fauna of British Columbia. These comparisons are consistent with the age range inferred from the brachiopods, except that there is no positive evidence, from the bryozoans, of the presence of Dzhulfian strata. These observations support previous views on the age of the Kapp Starostin Formation, for example, Forbes *et al.* (1958) and Flood *et al.* (1971).

The ranges of the bivalve species are shown in Figure 3. Only two species, *Vorkutopecten svalbardensis* and *V.* aff. *svalbardensis* have been found in the Vøringen Member. The overlying Svenskeegga Member is also poor in bivalves. Five species have been collected there, namely, *Etheripecten* cf. *mutabilis, Etheripecten wilczeki, Vorkutopecten svalbardensis, Acanthopecten licharewi*, and *Deltopecten* sp. All infrequently occur and their ranges extend up into the Hovtinden Member. Accordingly, the fauna is not essentially different from that of the Hovtinden Member.

Eight and ten species could be identified from the lower and upper parts of the Hovtinden Member, respectively. In addition to species ranging up from the Svenskeegga Member, *Streblopteria* cf. *eichwaldi, Streblopteria* ? sp. and *Palaeolima nakamurai* appear from the lower part, but they have not been found from the upper part. The upper part is relatively rich in bivalve fossils. *Grammatodon* (*Cosmetodon*) ? *suzukii*, *G.* (*C.*) ? sp., *Etheripecten keyserlingiformis, E.* aff. *sichuanensis, E.*? *alatus, Streblochondria winsnesi* and *Cassianoides sexcostatus* appear here.

The intimate relationship of the Spitsbergen fauna with that of the Russian Arctic region (Ural, Pechora, Russian Platform, Verkhoyansk) is shown by the occurrence of the following species :

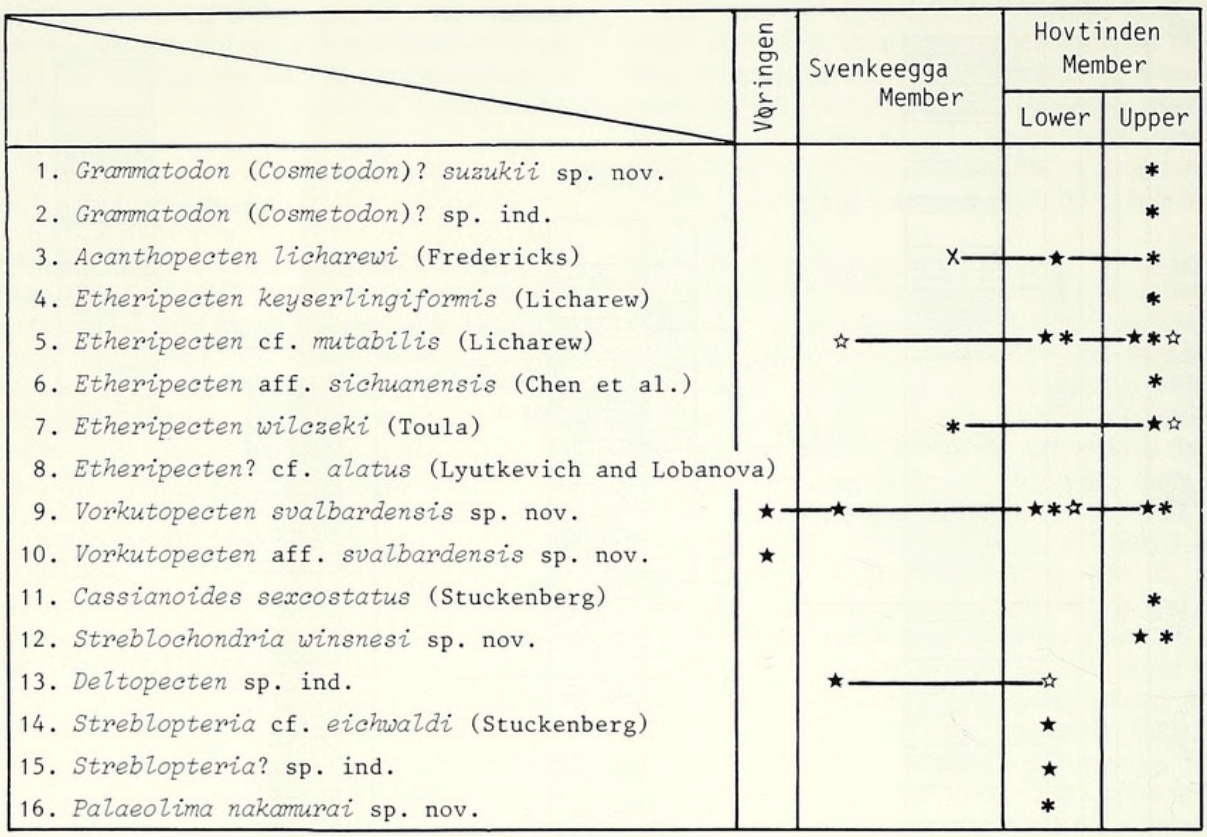

Figure 3. Compiled range-chart of bivalve fossils. *: Festningen, ☆: Reinodden, ★: Ahlstrandodden, ×: Skansbukta.

Acanthopecten licharewi (Asselian-Artinskian of the Urals, Kungurian of Pechora, Lower Permian of Verkhoyansk), *Etheripecten keyserlingiformis* (Upper Carboniferous?-Lower Permian of the Urals and Pechora), *E.* cf. *mutabilis* (Upper Carboniferous-Lower Permian of the Urals, Timan, Siberia), *E.? alatus* (Lower Permian of Pai Khoi in Siberia), *Streblopteria* cf. *eichwaldi* (Artinskian of the Urals and Russian Platform), and *Cassianoides sexcostatus* (Artinskian of the Urals and Russian Platform). *Cassianoides sexcostatus* is also reported from the Guadalupian of the United States (Branson, 1930; Ciriacks, 1963) and *Etheripecten sichuanensis* occurs in the Upper Permian of South China (Cheng *et al.*, 1974).

The stratigraphic occurrences of these species suggest that the Kapp Starostin Formation ranges in age from Artinskian to Kungurian. This is somewhat earlier than the age range inferred from the brachiopods and bryozoans, but the materials are poor and the conclusion is not definitive.

The Kapp Starostin Formation is conformably overlain by the Lower Triassic Vardebukta Formation of the Sassendalen Group (Nakazawa *et al.*, 1990; Nakamura *et al.*, 1990). The earliest Triassic age of the basal part of this formation is indicated by the occurrence of *Otoceras boreale* Spath together with *Claraia stachei* (Bittner) (Kortshinskaya, 1986; Nakazawa *et al.*, 1987). Hence, a time-gap corresponding at least to Dzhulfian-Dorashamian ages is indicated between the Permian and the Triassic beds.

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Systematic description

Order Arcoida Stoliczka, 1871
Family Parallelodontidae Dall, 1890
Subfamily Grammatodontinae Branson, 1942
Genus ***Grammatodon*** Meek and Hayden, 1861
Subgenus ***Cosmetodon*** Branson, 1942

Grammatodon (***Cosmetodon***)? ***suzukii*** sp. nov.

Figures 4-1a, b

Parallelodon sp. ind. Frebold, 1937, p. 55, pl. 1, figs. 8, 9.

Materials.—A pair of left and right external molds.

Holotype, Reg. no. HP 100050.

Etymology.—Dedicated to Dr. Hiroyuki Suzuki of Doshisha University, who worked in the field with the author.

Diagnosis.—Permian *Grammatodon* characterized by well developed, fine radial ribs and a little arcuate ventral margin.

Description.—Shell moderate in size, a little inflated, elongated subquadrate with subparallel dorsal and ventral margins, rounded anterior and truncated posterior margins; ventral margin slightly arcuate; 41 mm long and 19 mm high; umbo broad and low, raised above the hinge margin, situated at anterior one-fifth of shell length; bluntly rounded umbonal ridge running from the umbo to the posteroventral extremity; surface covered by numerous, weak radial striae, wider than the interstices, approximately fifteen per centimetre width on the medial surface of the shell, one centimetre from the umbo; densely spaced concentric growth lines form cancellate sculpture with the radials (Figure 4-1b); hinge and internal characters not observable.

Comparison.—Two incomplete specimens illustrated by Frebold (1937) from near the same horizon at Festung (= Festningen) are identical with the present species. Based on Permian material from Malaysia, Yancey (1985) pointed out the possibility that most of the Paleozoic species described as *Parallelodon* should be referred to *Grammatodon* (*Cosmetodon*). Although the present species does not show its hinge characters, it is identified with that genus on the basis of its external shape and ornament. It is similar to the Guadalupian *Cosmetodon multistriatus* (Girty, 1908, p. 423, pl. 31, figs. 13, 14) in its shape and weak radial ornament, but it differs from that species in having less numerous radial striae, a little arcuate ventral margin and a larger size.

Occurrence.—Rare in black shale of the uppermost fossil horizon, in the Hovtinden Member (F11) at Festningen.

***Grammatodon* (*Cosmetodon*)? sp. ind.**

Figures 4-2a, b

Genus (*Parallelodon*)? et sp. ind. Frebold, 1937, p. 56, pl. 2, fig. 4.

Material.—One incomplete, right external cast. Reg. no. HP 100051.

Description.—Posterodorsal marginal part is missing. Preserved part of the specimen is 30 mm long and 18.5 mm high. It is twice as long as high judging from the growth line. Surface is covered by numerous, close-set radial striae and growth lines which are very weak, but visible under the magnifying glass. The radials reach about forty per centimetre width on the medial part of the shell, one centimetre from the umbo (Figure 4-2b).

Discussion.—The present material most probably belongs to the species doubtfully referred to *Parallelodon* by Frebold (1937) from Festningen. It is similar to *G.* (*C.*)? *suzukii* in shape, but differs from it in more densely spaced and more irregular radial ornament. In its numerous radial striae it is similar to *Grammatodon multistriatus* (Girty), but it has a different shape with a more convex ventral margin than the latter species. Evidence is not adequate to support a new species for this specimen.

Occurrence.—Locality and horizon are identical with those for the preceding species.

Order Pterioida Newell, 1965
Superfamily Pectinacea Rafinesque, 1815
Family Aviculopectinidae Meek and Hayden, 1864
Subfamily Aviculopectininae Meek and Hayden, 1864
Genus ***Acanthopecten*** Girty, 1903

Acanthopecten licharewi (Fredericks, 1915)

Figures 4-3—5

Pterinopecten Licharewi Fredericks, 1915, p. 28, pl. 1, fig. 14.
Aviculopecten (*Acanthopecten*?) *licharewi* (Fredericks). Licharew, 1927, p. 91, pl. 6, fig. 24.
Acanthopecten licharewi (Fredericks). Muromtseva, 1984, p. 66, pl. 25, fig. 26; pl. 28, figs. 7, 8, 11, 12.

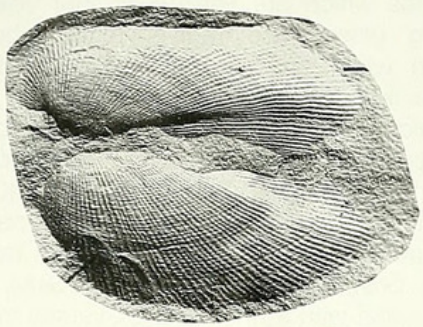
Materials.—One nearly complete and one incomplete external cast of left valves, an incomplete external mold of a left? valve, and an incomplete external mold of a right valve. Reg. nos. HP 100052~55.

Description.—All the specimens are incomplete internal molds or somewhat abraded external casts, and the details of the ornament are imperfectly preserved.

Shell small, subequivalve, subcircular in shape; left valve a little inflated; right valve nearly flat; anterior auricle of left valve trigonal and sharply defined; posterior auricle relatively large, flat, alate and protruding posterodorsally, but not sharply defined from the disc. Shape variable, probably due to secondary deformation; one left valve of nearly equal height and length, with an apical angle of 100° (Figure 4-3) and another left valve more elongate (L/H ratio of 1.34) with

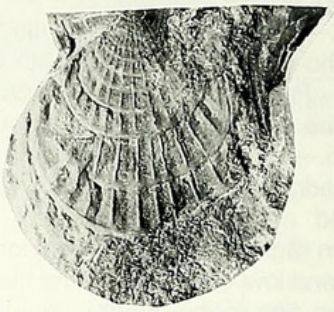
Table 1. Measurements of *Acanthopecten licharewi* (Fredericks). Abbreviations and notation of Tables 1-8. L: length, H: height, U: distance of umbo from the anterior end of the shell, l: hinge length, r: total number of radial ribs, $r_{1,2}$: number of primary and secondary radials, respectively, $r_{2\sim4}$: number of secondary to fourth-order radials between primary radials, r_{3+4}: number of third- and fourth-order radials between primary and secondary radials, c: number of comarginal lamellae or costae, a: apical angle (in degrees), V: valve (R: right, L: left), *: estimated value, linear dimensions in mm, Hor.: horizon.

Reg.	no.	L	H	H/L	a	r	c	V	Hor.
HP	100052	23.0	19.5*	0.85	100	13	11	L	AP 6
HP	100055	20.5+	—	—	120	17	9+	R	AP 6
HP	100054	28.5	22+	—	—	14+	6+	R	AP 6
HP	100053	14+	14.8	—	—	8+	7	L	SA 7



1a

2a



3

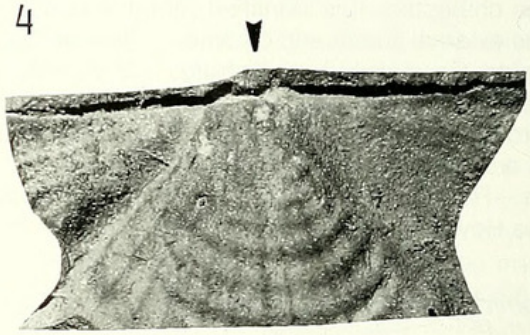
2b

1b

4

5

6

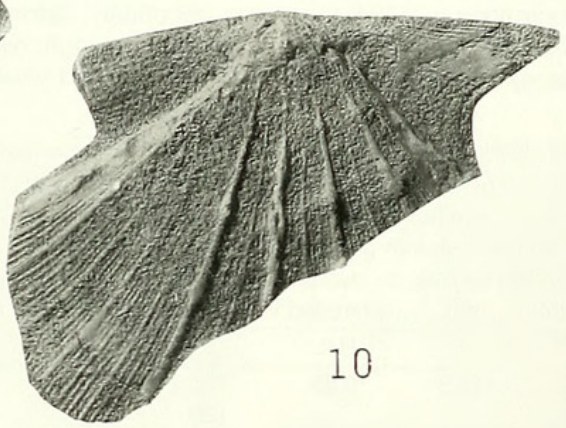


7b

7a

8

11



10

9

12

a larger apical angle, 120°; radial ribs narrow and widely spaced varying in number from 13 to 17; interspaces between radials slightly concave or nearly flat; lamellose comarginal sculpture widely disposed, becoming wider later in growth stage with distally oriented spines in the middle of the interspaces of the radial ribs (Figure 4–5).

Discussion.—This species is similar to the Lower Permian *Acanthopecten licharewi* (Fredericks, 1915) from the Urals, Pechora and Verkhoyansk, and to the Upper Carboniferous *Acanthopecten carbonarius* (Stevens) reported from the United States (e.g., Newell, 1938), China (Chao, 1927), and the Donetz Basin (Jakowlew, 1903) in its small size and relatively small number of radial ribs. According to Muromtseva (1984), *A. licharewi* is distinguished from *A. carbonarius* in having less numerous radial ribs and completely flat interspaces between the radials. In these respects, the present material is identical with *A. licharewi*.

Occurrence.—Rare in calcareous shale or muddy siliceous limestone of Unit 5 (lower part of Hovtinden Member) at Ahlstrandodden (AP 6), and in black shale of Unit 7 (upper part of Svenskeegga Member) at Skansbukta (SA 7). According to Thore S. Winsnes (personal communication, 1995) it also occurs in Permian strata in the valley north of Stensiöfjellet, inner Sassendalen.

Subfamily Etheripectininae Waterhouse, 1982
Genus ***Etheripecten*** Waterhouse, 1963

Discussion.—This genus was introduced by Waterhouse (1963) based on *Etheripecten striatura* Waterhouse from the Upper Permian of New Zealand. The ornament of the left valve resembles that of "*Aviculopecten*" with radial ribs increasing in number by insertion and differentiated into more than two orders. The radial ribs of the right valve of this species also increase in number by insertion, but are usually weaker and less differentiated than those of the left valve. In "*Aviculopecten*", the number of radial ribs of the right valve increases by bifurcation or ramification. In this respect, *Etheripecten* is similar to *Limipecten*, but according to Waterhouse (1969) the concentric lamellae between radial ribs of *Etheripecten* point dorsally, while those of *Limipecten* point ventrally as in the case of *Aviculopecten planoradiatus* M'Coy, the type species. Recently, Newell and Boyd (1995) reexamined the Late Paleozoic pectinoids. They defined *Aviculopecten* and Aviculopectinidae as bivalves with equiconvex shells, provided with simple plicae in both valves. On the other hand, the family Etheripectinidae is characterized by inequiconvex and paradiscordant shells, with multicostate ornament. Newell and Boyd stressed the variability of multiplicated ribbing and concentric sculpture in this family, treating the genera *Aviculopecten* and *Deltopecten* of authors, *Etheripecten* Waterhouse, *Paradoxipecten* Zhang, *Corrugopecten* Waterhouse, *Fletcheripecten* Waterhouse and *Squamuliferipecten* Waterhouse as synonyms of *Heteropecten* Kegel and Costa. In this case, *Heteropecten* contains a vast number of species with various kinds of ornamentation. In this paper, *Etheripecten* is treated as a distinct genus from *Heteropecten*, the type species of which, *Aviculopecten catharinae* Reed, has broad and bifurcated radial ribs in the right valve. *Fletcheripecten* and *Paradoxipecten* are here considered to be synonyms of *Etheripecten*.

Etheripecten keyserlingiformis (Licharew, 1927)

Figures 4–6, 7a, b

Pecten (*Aequipecten*) ? *keyserlingiformis* Licharew, 1927, p. 33, pl. 3, figs. 1–3; Frebold, 1937, p. 52, pl. 7, fig. 7.
Aviculopecten keyserlingiformis (Licharew). Muromtseva, 1984, p. 60, pl. 28, fig. 10.

Materials.—One nearly complete, left semiexternal cast (HP 100056) and one incomplete, left internal mold (HP 100057).

Description.—Shell medium in size, pectiniform, a little inflated, prosocline, extended posteroventrally; disc fan-like in shape with slightly arcuate anterodorsal, nearly straight posterodorsal, and rounded ventral margins; anterior auricle trigonal with slightly convex anterior margin; posterior auricle a little larger than anterior one, sinuated posteriorly; hinge margin straight, shorter than shelllength; ligament area narrow, nearly smooth, provided with a trigonal alivincular ligament pit beneath the umbo (Figure 4–7b); umbo not prominent, slightly salient above the hinge margin, situated at about anterior two-fifths of shell length; surface ornamented with nine or ten slender primary radial ribs alternating with secondaries, some of which become as strong as the primaries; two or three radial riblets of third and fourth order inserted in each interspace; strong concentric folds developed over the whole surface of the disc, more widely spaced in later growth stage; three radial ribs observable on anterior auricle, and obsolete ones on posterior auricle.

Discussion.—These specimens are identical with *Pecten* (*Aequipecten*) *keyserlingiformis* reported by Licharew (1927) and Frebold (1937), in its characteristic ornamentation. Probably due to secondary deformation, one specimen (Fig-

Figure 4. **1a, b.** *Grammatodon* (*Cosmetodon*) ? *suzukii* sp. nov., 1a: a pair of external molds of left and right valves, holotype (HP 100050), 1b: enlarged figure showing details of sculpture, ×2.5. **2a, b.** *Grammatodon* (*Cosmetodon*) ? sp., 2a: right external cast (HP 100051), 2b: enlarged figure showing details of sculpture, ×4. **3–5.** *Acanthopecten licharewi* (Fredericks), 3, 4: left semiexternal casts (HP 100052 and 53), ×2 and ×1.5, 5: right external mold (HP 100054), ×1.5. **6, 7a, b.** *Etheripecten keyserlingiformis* (Licharew), 6: left semiexternal cast (HP 100056), 7a: left semiexternal cast (HP 100057), 7b: enlarged figure showing alivincular ligament pit (arrow), ×2.5. **8, 9.** *Etheripecten wilczeki* (Toula), 8: gypsum cast of left external mold (HP 100058), ×1.5, 9: left external mold (HP 100059), ×2. **10.** *Etheripecten* sp. aff. *E. sichuanensis* (Chen *et al.*), gypsum cast of left external mold (HP 100060). **11, 12.** *Etheripecten* sp. cf. *E. mutabilis* (Licharew), 11: gypsum cast of left external mold (HP 100062), 12: left semiexternal cast (HP 100071). All are in natural size unless otherwise indicated.

Table 2. Measurements of *Etheripecten keyserlingiformis* (Licharew).

Reg.	no.	L	H	H/L	r_{1+2}	r_{3+4}	a	c	Hor.
HP	100056	45.5	40.0	0.89	18	3	115	15	F 11
HP	100057	—	17.6	—	15_+	1～2	90	11	F 11

ure 4-6) is extended posteroventrally and has a more elongated shape than the previously described species, but another (Figure 4-7a) has a shape and ornamentation similar to the type specimen. Although the right valve of this species has not been reported, the shape and ornamentation of its left valve are very similar to those of *Etheripecten striatura* Waterhouse, the type species of the genus, so the species is here included in *Etheripecten*.

Occurrence.—Rare in black shale of the uppermost fossil horizon of the Hovtinden Member at Festningen (F11).

Etheripecten wilczeki (Toula, 1875)

Figures 4-8, 9

Pecten (*Aviculopecten*) *Wilczeki* Toula, 1875a, p. 152, pl. 1, fig. 12.
Pecten wilczeki Toula. Frebold, 1937, p. 54.

Materials.—One nearly complete, left external mold and several fragmental molds of left valves. Reg. nos. HP 100058, 59.

Description.—Shell relatively small, pectiniform, a little inflated; fan-like in shape, with nearly straight anterodorsal, slightly dorsally arcuate posterodorsal, and rounded ventral margins; prosocline, extended posteroventrally; umbo not prominent, slightly salient above the hinge margin, lying at about anterior two-fifths of shell length; apical angle 95-110°; anterior auricle small, trigonal; posterior auricle a little larger than the posterior one, alate with arcuate posterior margin; both auricles sharply distinct from disc; surface of the shell ornamented with nine primary radial ribs; wide, nearly flat interspaces are sculptured by 8-12 weak, radial threads, some a little stronger than the rest referred to as secondary ribs, but not alternating with the primaries; umbonal part of the shell, to 16 mm, ornamented with concentric wrinkles, which later fade away; two or three radial striae discernible on both auricles; ligament unknown.

Comparison.—The type specimen described by Toula has seven strong, slender radial ribs, and smooth interspaces without finer radial ribs. *Pecten* (*Aequipecten*) ? *wilczekiformis* Licharew (1927, p. 35, pl. 3, figs. 4, 6, 7) is distinguished from *E. wilczeki* in its development of interstitial radial riblets.

According to Frebold (1937) the type specimen of *E. wilczeki* is not well preserved. He recognized the presence of finer radial ribs in the marginal area of his specimen, where the shell is preserved, and regarded the two species as being conspecific. However, the finer interstitial radial ribs of the specimen described here are very weak, numerous and subequal in strength, whereas those of *P.*(*A.*) ? *wilczekiformis* are differentiated into second, third or even fourth orders. Both species are considered to belong to *Etheripecten*. *E. wilczekiformis* is more closely allied to *E. keyserlingiformis* than to *E. wilczeki*. *E. wilczeki* is most similar to *Euchondria cancellata* Gu and Liu (1976, p. 171, pl. 12, figs. 17, 18), from the Lower Permian Kufeng Series of South China, in shape and ornament. It differs only a little from the latter species in its lesser development of concentric folds and greater height relative to length. The genus *Euchondria* is characterized by a costate left valve, a nearly smooth right valve, and a series of ligament pits perpendicular to the hinge margin, in addition to a large, central ligament pit. In *E. cancellata* only left valves are known and the hinge character is unknown. Therefore, its generic position is uncertain.

Occurrence.—Rare in calcareous shale of the uppermost horizon of the Svenskeegga Member at Festningen (F5); rare in muddy limestone of the upper part of the Hovtinden Member at Ahlstrandodden (AP 7, 8) and Reinodden (RP 9).

Etheripecten sp. aff. ***E. sichuanensis*** Chen, Zhang and Xu, 1974

Figures 4-10

Resembles.—
Etheripecten sichuanensis Chen, Zhang and Xu, 1974, p. 302, pl. 158, figs. 14, 17; Fang, 1987, p. 373, pl. 2, figs. 1-6.
? *Etheripecten sichuanensis* Liu, 1976, p. 179, pl. 13, figs. 10-13; Gan and Yin, 1978, p. 336, pl. 14, figs. 17, 20.
Etheripecten hunanensis Zhang, 1981, p. 261, pl. 2, figs. 6-8.

Material.—One incomplete left external mold obtained by dissolving away shell material. Reg. no. HP 100060.

Description.—Shell relatively large, a little inflated, longer than high, estimated to be 65 mm long and 58 mm high; disc fan-like in shape with straight antero- and posterodorsal margins and a broadly rounded ventral margin; hinge margin straight, a little shorter than shell length; anterior auricle small, subtrigonal, a little inlated, clearly separated from the disc by a sulcus; posterior auricle large, flat, sinuated posteriorly, protruding posterodorsally; umbo subdued, slightly salient above hinge margin; apical angle 110°; surface ornamented with radial ribs of three orders; primaries seven in number, strong and round-topped, alternating with weaker secondaries; five to six, thread-like rdial riblets of third order inserted in each interspace; auricles with radial and concentric sculpture making a lattice ornament; hinge not preserved.

Discussion.—The external shape and the ornamentation indicate a close relationship of this species with *Etheripecten sichuanensis* Chen, Zhang and Xu (1974) and *E. hunanensis* Zhang (1981), both from the Upper Permian Luntang Series in South China. The former species was later illustrated as ? *E. sichuanensis* sp. nov. by Liu (1976) based on the same specimens. Zhang distinguished *E. hunanensis* from *E. sichuanensis* by the presence of striations and spinose projections on the primary ribs. According to Fang (1987), however, these differences represent infraspecific variation.

The specimen described here differs from *sichuanensis* in its more elongate shape with larger apical angle and larger size.

Occurrence.—Arenaceous limestone of the upper part of the Hovtinden Member at Festningen (F8).

Etheripecten sp. cf. ***E. mutabilis*** (Licharew, 1927)

Figures 4-11, 12 ; Figures 5-1—4

Pecten (*Aequipecten*) *Kokscharofi* Toula (non Verneuil), 1873, p. 20, pl. 5, fig. 6.
Aviculopecten cf. *hiemalis* Salter. Licharew, 1927, p. 76, pl. 5, figs. 18-21 ; pl. 6, fig. 1.
? *Aviculopecten* (*Deltopecten*) cf. *mutabilis* Licharew and *A.* cf. *hiemalis* Salter. Frebold, 1937, p. 51, pl. 1, figs. 2, 3.
Compared with.—
Pecten (*Aequipecten*) *Bouei* Toula, 1873, p. 19, pl. 5, fig. 8.
Aviculopecten mutabilis Licharew, 1927, p. 72, pl. 5, figs. 7-10, 12, 14-17.
Aviculopecten (*Deltopecten*) ? *mutabilis* Licharew. Lyutkevich and Lobanova, 1960, p. 102, pl. 15, figs. 1-6.

Material.—Eight incomplete left valves, one complete and two incomplete right valves. Reg. nos. HP 100061~68, 100070, 71.

Description.—Shell moderate in size, inequivalve, inequilateral, prosocline, nearly as long as high, apical angle 90-100°. Left valve moderately inflated ; umbo not prominent, a little salient above the hinge margin ; beak situated at about anterior one-third of shell length ; disc fan-like in shape with slightly concave anterodorsal, nearly straight posterodorsal, and well rounded ventral margins ; anterior auricle subtrigonal, with a rounded anterior margin, demarcated from the disc by a sulcus ; posterior auricle only partly preserved ; surface covered with many radial ribs differentiated into three or four orders ; primary ribs 7 to 9 in number, strong, round-topped, a little projected at ventral margin ; second- and third- order radials alternating regularly with lower-order radials ; some tertiary radials as strong as secondaries ; fourth-order radials very weak, sporadically inserted near the margin ; growth lines close-set, curving ventrally on radial ribs and dorsally on interspaces, showing scaly or spinose projections on the primary ribs (Figures 5-1b, 2). Right valve nearly flat ; anterior auricle deeply incised below ; posterior auricle subtrigonal, nearly equal in length to the anterior auricle, a little sinuated posteriorly ; numerous radial ribs increasing in number by insertion ; first- and second-order radials becoming subequal in strength ; a small number of third-order radials, very weak and thread-like ; total number of radials, 34 ; close-set, weak concentric sculpture, making a lattice ornament with the radials ; alivincular ligament pit partly seen in one left internal mold.

Remarks and comparison.—In this material, the number of radial ribs increases by insertion in both the left and right valves. The comarginal sculpture curves ventrally on the radial ribs and dorsally on the interspaces. Therefore, these specimens are referred to *Etheripecten* Waterhosue (1969). In their well differentiated radial ornament and robust primary radial ribs, these shells are identical with *Pecten* (*Aequipecten*) *kokscharofi* as described by Toula (1873), *Aviculopecten* cf. *hiemalis* Licharew (1927), and probably *Aviculopecten* (*Deltopecten*) cf. *mutabilis* and *A.* (*D.*) cf. *hiemalis* Frebold (1937). They are very similar to *Aviculopecten mutabilis* Licharew (1927). According to Licharew (1927) the latter species is distinguished from *Aviculopecten* cf. *hiemalis* by its more pointed posterior auricle, the sharper restriction of auricles from the disc, the weaker bend of antero- and posterodorsal margins of the disc, and less regularity in the appearence of ribs. These differences, though, are not distinctive, as noted by Licharew himself. *A.* cf. *hiemalis* of Licharew has generally more robust primary radials than *A. mutabilis*. It is clearly distinguished from the original *A. hiemalis* reported from the Himalayas (cf. Diener, 1897, p. 9, pl. 5, figs. 10a, b, 11) in taller shape and smaller posterior auricle and is more closely related to *A. mutabilis*. Lyutkevich and Lobanova (1960) illustrated the right valve of *A. mutabilis* (pl. 15, figs. 2, 5), which shows inserted radial ribs. Therefore, *A. mutabilis* is considered to belong to the genus *Etheripecten*. The right valve of *Etheripecten mutabilis* has less uniform radial ornament than the present species.

Occurrence.—Common in the Hovtinden Member at Festningen, Reinodden, and Ahlstrandodden ; rare in Svenskeegga Member at Reinodden.

Etheripecten ? sp. cf. ***E. alatus***
(Lyutkevich and Lobanova, 1960)

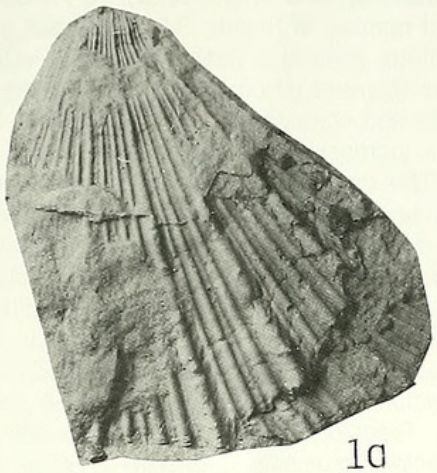
Figures 5-5

Compared with.—
Pseudomonotis alata Lyutkevich and Lobanova, 1960, p. 116, pl. 17, fig. 9.

Description.—Only one incomplete, semiexternal cast of a

Table 3. Measurements of *Etheripecten* sp. cf. *E. mutabilis* (Licharew). ☆ : Total number of primary and secondary radial ribs, # : total number of radial ribs.

Reg.	no.	L	H	H/L	U	U/L	r_1	$r_{2\sim4}$	a	V	Hor.
HP	100060	60_+	58_+	—	—	—	7_+	4~6	100	L	F 9
HP	100062	21.5	22.8	1.06	—	—	7	3	85	L	RP 3
HP	100063	22.3	21.5	0.96	8.0	0.36	26☆		90	R	F 11
HP	100064	30_+	32_+	—	—	—	6_+	3~4	—	L	F 9
HP	100065	33.5	35.0	1.04	12.5	0.37	9	3~5	90	L	F 11
HP	100066	21.0	—	—	—	—	24#		85	R	F 11
HP	100067	25.0	25.0	1.00	7.5	0.30	8	3~4	90	L	F 11
HP	100071	25.3	25.7	1.02	10.5	0.42	7	3	90	L	F 7p



1a

1b

3

4

2

6

7

5

8

9

10

11

12

left? valve is available (Reg. no. HP 100069). More than posterior one-third of the shell is not preserved. Shell 38 mm high and more than 30 mm long, nearly flat; disc inferred to be fan-like in shape; anterodorsal margin straight; anterior auricle trigonal, flat, clearly marked off from the disc; surface ornamented with six strong, round-topped primary radial ribs; broad, flat or slightly concave interspaces with weak secondary and tertiary radials five to eight in number; close-set weak concentric striae partly preserved.

Discussion.—The present material is quite similar in shape and sculpture to *Pseudomonotis alata*, described on the basis of a right valve by Lyutkevich and Lobanova (1960) from the Lower Permian at Pai Khoi of the northern coast of Siberia. It differs slightly from that species in taller outline. The well differentiated, straight radial ornament of these Siberian and Spitsbergen species suggests that they belong to *Etheripecten* rather than to *Pseudomonotis*.

Occurrence.—Dark grey calcareous shale of Unit G of the Hovtinden Member at Reinodden (RP 9).

Family Streblochondriidae Newell, 1938
Genus ***Streblochondria*** Newell, 1938

Streblochondria winsnesi sp. nov.

Figures 6-2a, b—4

Pecten (*Pseudamusium*) cf. *ufaensis* Tschernyschew. Frebold, 1937, p. 53, pl. 1, fig. 3-5.

Material.—One complete right valve (external and internal molds, holotype, Reg. no. HP 100094a, b) and a nearly complete right valve (internal and external molds, Reg. no. HP100095a, b). Holotype specimen occurs in black shale of Unit 11 of the Hovtinden Member at Festningen.

Etymology.—Dedicated to Thore S. Winsnes for his contribution to the geological understanding of West Spitsbergen.

Diagnosis.—Permian *Streblochondria* characterized by a broad shape and very fine cancellate ornament composed of numerous radial and concentric striae.

Description.—Shell medium in size, a little inflated, and subcircular in shape, with well rounded ventral, slightly convex posterodorsal, and slightly concave anterodorsal margins; as long as high; opisthocline; umbo subdued, not salient above the hinge margin; apical angle varying from 90° to 110°; posterior auricle very small, obtuse-triangular, truncated posteriorly; anterior auricle relatively large, rounded trigonal, and marked below by deep slit-like byssal notch; surface covered with numerous, uniform radial striae increasing in number by insertion, 70 per cm in the medial area 1 cm away from the umbo; dense concentric fila making a cancellate ornament with the radials, slightly raised scales on the radials; anterior auricle ornamented with five distinct radial ribs and growth lines; hinge characters unknown.

Table 4. Measurements of *Streblochondria winsnesi* sp. nov.

Reg.	no.	L	H	H/L	I	a	Hor.
HP	100094	33.5	ca33	0.99	9.5	90~110	F 11
HP	100095	20.0	20.0	1.00	—	90~110	AP 9

Discussion.—Frebold (1937) illustrated three right valves identified as *Pecten* (*Pseudamusium*) cf. *ufaensis* Tschernyschew from the upper part of the Kapp Starostin Formation at Festningen. One of them shows a distinct sculpture, very similar to that described here, so it is considered to be conspecific with this species. It is similar to *Streblochondria sculptilis* (Muller), the type of the genus, from the Carboniferous of the United States (cf. Newell, 1938, p. 38, pl. 16, figs. 5a-c, 7, 9a, b). However, the present new species has a larger apical angle, a lower outline, and finer ornament than that species. It is more closely allied to *S. ufaensis* (Tschernyschew) (Licharew, 1927, p. 30, pl. 2, figs. 7, 8; Lyutkevich and Lobanova, 1960, p. 131, pl. 21, fig. 1), but differs from that species in the finer radial sculpture as noticed by Frebold and, furthermore, in its longer outline.

Occurrence.—Rare in siliceous limestone of the upper part of the Hovtinden Member at Ahlstrandodden (AP 9), and the uppermost horizon of the Hovtinden Member at Festningen (F11).

Genus ***Streblopteria*** M'Coy, 1851

Streblopteria sp. cf. ***S. eichwaldi*** (Stuckenberg, 1898)

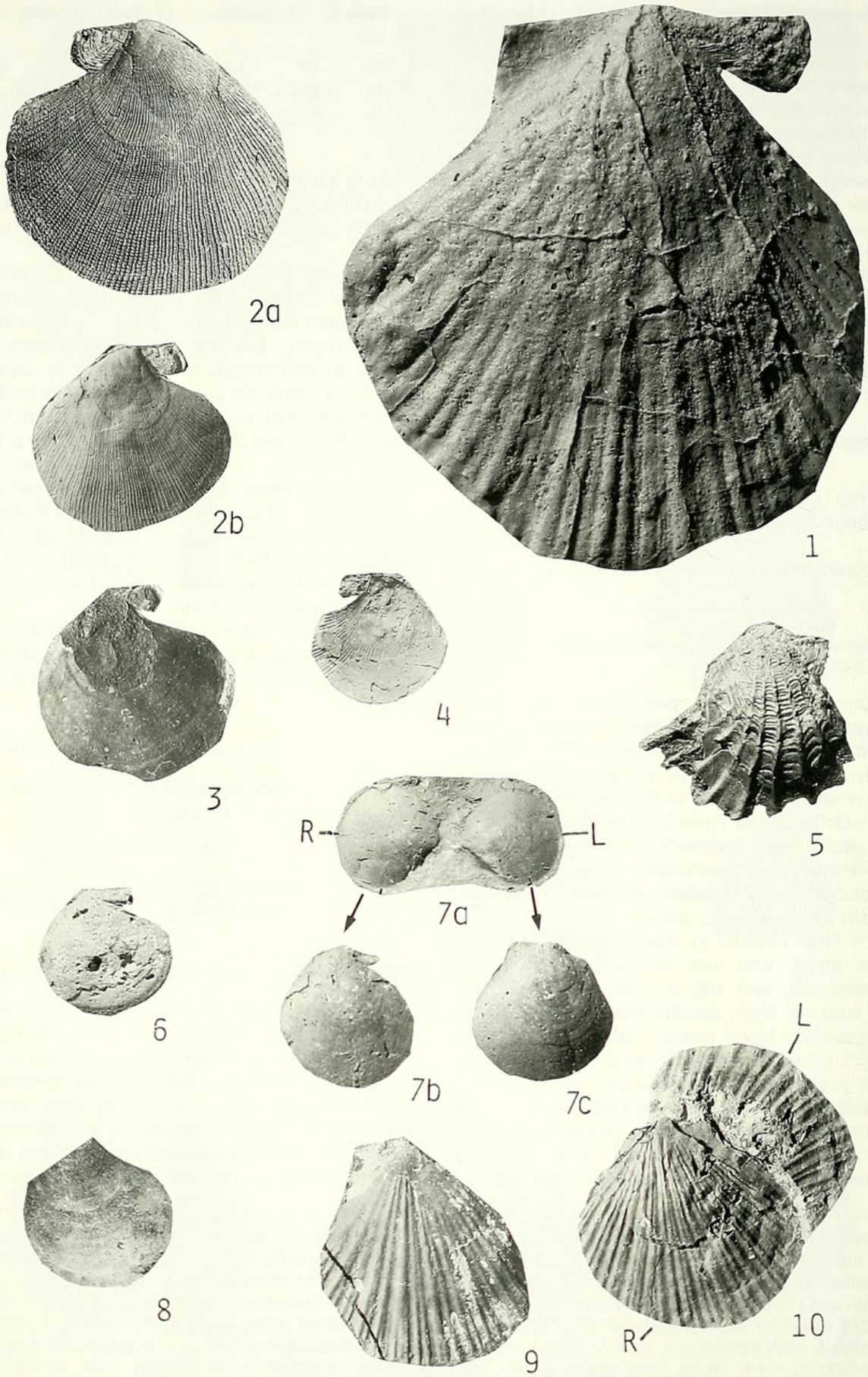
Figures 6-6, 7a, b, c

Pecten (*Aviculopecten*) cf. *ellipticus* Toula, 1873, p. 20, pl. 5, fig. 1.
Pecten (*Pseudamusium*) sp. ind. ex aff. *sericeus* Frebold, 1937, p. 54.
Compared with.—
Pecten Eichwaldianus Stuckenberg, 1898, p. 203, pl. 1, figs. 25a, b.

Materials.—A pair of valves, two internal molds, and two incomplete external molds. Reg. nos. HP 100087~90.

Description.—Shell small, nearly equivalve, subcircular in shape, opisthocline, a little extended anteriorly; left valve gently inflated; right valve slightly less convex than left; anterodorsal margin of the disc a little concave, ventral and posterior margins well rounded; umbo lying a little posterior to the middle of the shell, not salient above the hinge

Figure 5. **1-4**. *Etheripecten* sp. cf. *E. mutabilis* (Licharew), 1a: gypsum cast of left external mold (HP 100061), 1b: enlarged figure showing details of sculpture, ×3, 2: gypsum cast of left external mold (HP 100064), 3: silicon rubber cast of right external mold (HP 100066), 4: gypsum cast of right external mold (HP 100063). **5**. *Etheripecten*? sp. cf. *E. alatus* (Lyutkevich and Lobanova), left? semiexternal cast (HP 100069). **6-10**. *Vorkutopecten svalbardensis* sp. nov., 6: gypsum cast of right external mold, holotype (HP 100072), 7: semiinternal mold of left valve, paratype (HP 100076), 8: gypsum cast of right external mold (HP 100075) ×1.2, 9: gypsum cast of right external mold (HP 100077), 10: gypsum cast of right external mold (HP 100078), ×1.4. **11, 12**. *Deltopecten* sp., 11: semiexternal cast of left valve (HP 100085), ×1.1. 12: silicon rubber cast of external mold of right valve (HP 100086). All are natural size unless otherwise indicated.


2a
1
2b
4
3
5
R
L
7a
6
7b
7c
L
8
9
10
R

margin; apical angle 90° in umbonal portion and 110–120° in later growth stages; posterior auricle small, obtuse-triangular; anterior auricle larger, obtuse-triangular in left valve, and deeply incised below in the right valve; surface almost smooth, weak concentric sculpture discernible in the internal mold and partly preserved external cast; no radial ornament observed.

Discussion and comparison.—The genus *Streblopteria* was established by McCoy (1851). The Carboniferous *Meleagrina laevigata* McCoy from Ireland was designated as type species by Meek and Worthen (1866). The genus is characterized by smooth shells of acline to opisthocline pectinoid form, and is distinguished from *Streblochondria* Newell (1938) which has cancellate sculptures. The posterior auricle of the type species is much larger than the anterior auricle, poorly distinguished from the disc. However, the forms with a small, obtuse-triangular, more or less clearly defined posterior auricle are also included in *Streblopteria* or referred to *Pseudamusium* Verrill by many authors.

According to Cox *et al*. (1969) *Pseudamusium* is a junior synonym of the Cenozoic genus, *Palliolum* Monterosato. Several small *Pseudamusium* species, such as *P. eichwaldi* (Stuckenberg), *P. pusillus* (Schlotheim), and *P. ellipticum* (Phillips), have very weak radial ribs or cancellate ornament on a limited part of the shell. They were doubtfully assigned to *Streblochondria* by Newell (1938). However, they have a longer shape than *Streblochondria* and are more similar to smooth forms of *Streblopteria* or "*Pseudamusium*". This hardly warrants recognition as a different genus. In this paper, all these species are treated as *Streblopteria*, although they differ somewhat from the type species. The species described here is most similar to *S. eichwaldi* (Stuckenberg, 1898) in shape, but the surface ornament is insufficiently known for specific identification. *Pecten* cf. *ellipticus* reported by Toula (1873) from the south point of Spitsbergen was referred to *Pecten* (*Pseudamusium*) aff. *sericeus* Verneuil by Frebold (1937). However, *P. sericeus* has a more opisthocline shell that is extended more anteriorly. It is probably identical with the present species.

Occurrence.—Siliceous limestone of the lower part of the Hovtinden Member at Ahlstrandodden (AP 6).

Streblopteria ? sp. ind.

Figures 6–8

Discussion.—One incomplete right internal mold (Reg. no. HP 100092), estimated at 24 mm long and a little more than 24 mm high, is at hand. The shell is subcircular in outline and provided with a concave anterodorsal margin. The surface is covered by a weak concentric sculpture. The auricular part of the shell is not preserved. It probably belongs to *Streblopteria*, but is too imperfectly preserved to be certain.

Occurrence.—Siliceous shale of the lower part of the Hovtinden Member at Ahlstrandodden (AP 6).

Family Deltopectinidae Dickins, 1957
Genus ***Vorkutopecten*** Guskov, 1984

Vorkutopecten svalbardensis sp. nov.

Figures 5–6—10

Material.—Eight right external and internal molds and three left external and internal molds. Reg. nos. HP 100072~83 (holotype HP 100072). Holotype from Unit 9 of the Hovtinden Member at Festningen.

Etymology.—Derived from Svalbard Islands, where the species occurs.

Diagnosis.—Shell is higher than long; ornamentation of both left and right valves consists of numerous radial ribs differentiated into three orders, increasing in number by insertion. Concentric costae arch ventrally in the interspaces of radial ribs.

Description.—Shell inequivalve, inequilateral, suborbicular in shape, a little higher than long; right valve moderately to weakly inflated; left valve more inflated than right; umbo situated a little anterior to the middle of shell, nearly acline and slightly salient above the hinge margin in the left valve, but not in the right valve; apical angle about 90°; anterior and posterior auricles nearly equal in length; posterior one trigonal and sinuated posteriorly; right anterior auricle deeply incised below; surface of disc covered with numerous, slender radial ribs narrower than interstices, increasing in

Table 5. Measurements of *Streblopteria* sp. cf. *S. eichwaldi* (Stuckenberg).

Reg.	no.	L	H	H/L	I	I/L	U	U/L	a	V	Hor.
HP	100087a	8.0	7.5	0.94	4.0	0.50	4.0	0.50	~110	L	AP 6
HP	100087b	8.0	7.8	0.98	3.7*	0.46	4.5	0.56	90~120	R	AP 6
HP	100088	12.7	11.6	0.91	5.7	0.45	7.2	0.56	90~120	R	AP 6
HP	100089	13.0*	12.5	0.96	—	—	7.5	0.57	~120	R	AP 6

Figure 6. **1**. *Vorkutopecten* sp. aff. *V. svalbardensis* sp. nov., gypsum cast of right external mold (HP100084). **2–4**. *Streblochondria winsnesi* sp. nov., 2a: right external mold, holotype (HP 100094), ×1.4, 2b: gypsum cast, 3: right internal mold of the same, 4: right external mold (HP 100095). **5**. *Cassianoides sexcostatus* (Stuckenberg), left external mold (HP 100093), ×2.4. **6, 7a–c**. *Streblopteria* sp. cf. *S. eichwaldi* (Stuckenberg), 6: right internal mold (HP 100088), ×1.5, 7a: a pair of internal molds of left (L) and right (R) valves (HP 100087), ×2, 7b–c: enlarged figures of right (b) and left (c) valves, ×3. **8**. *Streblopteria* ? sp., right external cast (HP 100092). **9, 10**. *Palaeolima nakamurai* sp. nov., 9: right external cast, paratype (HP 100097), ×1.5, 10: right external cast (R), holotype (HP 100096) and a part of left valve (L), ×1.2. All are natural size unless otherwise indicated.

number by insertion; primary radial ribs varying in number from 12 to 17, with two or three radials of second and third orders in each interspace between the primaries; total number of radials 35 to 50 or more; secondary radials of right valve become as strong as primaries; lamellose concentric sculpture developed on the whole surface, curving dorsally on radial ribs and ventrally in interstices; both auricles sculptured by radial ribs and concentric costae; a small, trigonal ligament pit partly preserved in one left internal mold.

Remarks and comparison.—The radial ribs of both left and right valves increase in number by insertion, as in *Etheripecten, Limipecten*, and *Vorkutopecten*. The concentric sculpture swings ventrally between radial ribs as in *Limipecten*, not *Etheripecten*. The shell length of *Limipecten* is usually equal to or larger than the height, and the radial ribs of the right valve are finer and more numerous than those of the left valve. Furthermore, the right valve is nearly flat. The present species has a greater height than length. The ornamentaion is similar in both valves, although secondary ribs of the right valve grow as strong as the primaries. The right valve is more or less inflated. In these respects, it can be identified with *Vorkutopecten* established by Guskov (in Muromtseva, 1984), based on *Aviculopecten giganteus talis* Lyutkevich and Lobanova (1960, p. 108, pl. 16, fig. 10; pl. 17, fig. 1). Guskov included two species in the genus in addition to the type species, namely, *Aviculopecten subclathratus* (Keyserling) and *A. netschajewi* Licharew. However, the type specimen of the latter species has branching radial ribs in the right valve and is excluded from *Vorkutopecten*. On the other hand, materials described as *Vorkutopecten netschajewi* by Guskov (Muromutseva, 1984, pl. 29, fig. 8) have inserted radial ribs and cannot be identified with this species, which is more similar to *A. subclathratus*. The Spitsbergen species is similar to *A. subclathratus* and *A. netschajewi* of Guskov, but differs in its more numerous primary radial ribs and larger posterior auricle. *Vorkutopecten*, characterized by broad, alivincular ligament pit and a grooved ligament area, is included in Family Deltopectinidae. The present species has a relatively small ligament pit.

Occurrence.—Common in siliceous limestones of the Hovtinden Member at Festningen (F 7p, F 8 and 9), rare in limestone of the Vøringen Member (AP 1), common in siliceous limestone of the Svenskeegga (AP 2) and the Hovtinden Member (AP 6, 7) at Ahlstrandodden, rare in calcareous sandstone of the Hovtinden Member at Reinodden (RP 7).

Vorkutopecten sp. aff. ***V. svalbardensis*** sp. nov.

Figures 6-1

Discussion.—The species is represented by a single, large external mold of a right valve (Reg. no. HP 100084). It is 86 mm long and 91 mm high and has an apical angle of 100°. The shell is gently convex and sculptured with as many as 60 radial ribs. The radials are differentiated into three orders, but due to poor preservation distinction between primary and secondary ribs is difficult. This species is very similar to the preceding new species in shape and ornamentation, but its size is much larger and its apical angle is a little greater.

Occurrence.—Arenaceous limestone of Unit 1 (Vøringen Member) at Ahlstrandodden (AP 1).

Genus ***Deltopecten*** Etheridge, Jr., 1892

Deltopecten sp. ind.

Figures 5-11, 12

Material.—One incomplete left semiexternal cast, and one incomplete right valve represented by external and internal molds. Reg. nos. HP 100085, 86.

Description.—Shell moderate in size, subcircular in shape, nearly equiconvex and subequilateral; umbo not prominent, located subcentrally; apical angle 100-110°; anterior auricle triangular, with slightly concave anterior margin in the left valve and byssate in the right valve; left posterior auricle not preserved; right posterior one partly preserved, obtuse-triangular and probably smaller than the anterior one; surface of the left valve sculptured by relatively slender, rounded primary ribs, 18 in number, separated by wide interspaces and alternating with very weak, secondary radials; right valve ornamented with flat-topped primary radial ribs; intervening flat interspaces of a width nearly equal to that of the radial ribs, with weak secondary radials inserted in the medial part of the shell; surface of both valves covered with close-set concentric fila swinging slightly ventrally, in the interspaces; ligament not preserved.

Discussion.—Although the ligament cannot be observed, the present species can be referred to *Deltopecten* judging from the nearly equiconvex shell and relatively simple, flat-topped radial ribs. This species is somewhat similar to

Table 6. Measurements of *Vorkutopecten svalbardensis* sp. nov.

Reg.	no.	L	H	H/L	I	U/L	a	r_1	r	V	Hor.
HP	100072	31.0*	30.5*	0.98	19+	0.48	88	16	54	R	F 9
HP	100074	29.0	31.5	1.09	20.0	0.38	90	11?	47	R	F 7p
HP	100075	35.0	38.0	1.09	35.0	0.46	88	17	46+	R	F 9
HP	100076	24.0*	27.0	1.13	—	0.46	85	14	30+	L	AP 1
HP	100077	20.0*	22.0	1.10	—	0.50	90	12	42	R	F 7p
HP	100078	27.0*	28.7	1.06	22.0	0.50	90	12	40	L	AP 1
HP	100080	34.3*	35.8	1.04	26.0	0.43	90	12	37	R	AP 2
HP	100081	26.0*	30.3	1.17	13.0	0.49	90	?	35	R	AP 7

Table 7. Measurements of *Deltopecten* sp. ind.

Reg.	no.	L	H	H/L	U	U/L	a	r_1	V	Hor.
HP	100085	35.5	33.5	0.94	16.7	0.47	105	18	L	RP 7
HP	100086	30+	35.0	–	17.5	0.50	110	15?	R	AP 2

Deltopecten lyonsensis Dickins (1957, p. 41, pl. 7, figs. 1–5 and 9; pl. 8, figs. 11–13; pl. 9, fig. 12; pl. 10, figs. 3–4) from West Australia, but differs from that species in its less numerous primary radial ribs and the development of secondary radials in the left valve.

Occurrence.—Rare in calcareous sandstone of Unit E of the Hovtinden Member at Reinodden (RP 7) and in siliceous limestone of Unit 3 of the Svenskeegga Member at Ahlstrandodden (AP 2).

Family Cassianoididae Newell and Boyd, 1995
Genus ***Cassianoides*** Newell and Boyd, 1995

Discussion.—The present family and genus were established by Newell and Boyd (1995) on the basis of a single species, *Cassianoides kingorum* Newell and Boyd of the Middle to Late Permian of West Texas. The genus is characterized by small, strongly inequivalve shells; the left valve is strongly convex, ornamented with a few widely spaced, strong primary costae and a few comarginal, tubular hyote spines on the radial ribs; the right valve is flat, sculptured by spineless, subdued radial ribs. *Cyrtorostra sexradiata* Branson (1930, p. 45, pl. 11, figs. 13–15) from the Upper Permian Park City Formation was later shifted to the genus *Cassianella* of the Family Cassianellidae by Ciriacks (1963). This species was considered to be a junior synonym of *Pseudomonotis sexcostatus* Stuckenberg (1898, p. 207, pl. 1, fig. 40) from the Permian of Russia and to belong to *Aviculopecten* by Muromtseva (1984). The species is very similar to *Cassianoides kingorum*, not only in shell form but also in the characteristic ornamentation of both the left and right valves. It undoubtedly belongs to *Cassianoides*.

Aviculopecten crassispinosus Chronic, reported by Newell *et al*. (1953, p. 155, pl. 33, figs. 10–13) from the Lower Permian of Peru, is also referred to as a member of this genus. *Cassianella rara* described by Waterhouse (1987, p. 145, pl 3, figs. 1, 7, 10) from the Middle Permian of East Australia is another example. Waterhouse noticed the close relation of this species to *C. sexradiata* and *C. crassispinosus*. His figs. 1 and 7, illustrated as a right valve, are quite similar to the left valve of *A. crassispinosus* (especially fig. 13a of Newell *et al*., 1953), and are believed to be a left valve. The genus *Crassinoides* is now known from the Permian of the United States, Peru, Australia, Russia, and Spitsbergen.

Cassianoides sexcostatus (Stuckenberg, 1898)

Figure 6–5

Pseudomonotis sexcostatus Stuckenberg, 1898, p. 207, pl. 1, fig. 40.
Cyrtorostra sexradiata Branson, 1930, p. 45, pl. 2, figs. 13–15.
Cassianella sexradiata (Branson). Ciriacks, 1963, p. 45, pl. 5, figs. 5–7.
Aviculopecten sexcostatus (Stuckenberg). Muromtseva, 1984, p. 61, pl. 27, fig. 6; pl. 33, figs. 10–13.

Material.—Only one external mold of a left valve. Reg. no. HP 100093.

Description.—Shell small, 14 mm long and 14 mm high, strongly inflated; umbo narrow, orthogyrate, salient above the hinge margin and curving down over the hinge; anterior auricle rounded-trigonal, a little inflated and marked off from the disc by a deep and wide sulcus; posterior auricle imperfectly preserved, relatively small, obtuse-triangular, with its posterior margin weakly sinuated and set off from the disc by a strong, posterior, radial marginal rib; surface ornamented with nine slender but sharply raised radial ribs, projecting ventrally at ventral margin; interspaces between radials wide, slightly concave; distinct, regular concentric fila, closely spaced, curving dorsally in the interspaces, and with comarginal spinose projections on the radials; hinge margin straight, shorter than shell length; hinge not preserved.

Remarks.—The present specimen differs from the type in its more numerous radial ribs, but this is considered to be due to infraspecific variation. *Crassianoides sexcostatus* can be distinguished from *C. crassispinosus* (Chronic) by its weaker radial ribs and less spinose concentric sculpture, and from *C. rara* (Waterhouse) by the absence of secondary radial riblets.

Occurrence.—Black siliceous shale of the uppermost fossil horizon of the Hovtinden Member at Festningen (F11).

Superfamily Limacea Rafinesque, 1815
Family Limidae Rafinesque, 1815
Genus ***Palaeolima*** Hind, 1903

Palaeolima nakamurai sp. nov.

Figures 6–9, 10

Materials.—External casts and molds of a complete right valve and an incomplete left valve, and a nearly complete external cast of a right valve. Reg. nos. HP 100096 (holotype) and 100097. Holotype specimen occurs in shale of Unit 7 of the Hovtinden Member at Festningen.

Diagnosis.—Broadly rounded *Palaeolima* ornamented with wide, rounded, branching radial ribs intercalated with narrow furrows.

Etymology.—Dedicated to Dr. K. Nakamura, who surveyed West Spitsbergen several times as a leader of the Japanese Expedition.

Description.—Shell equivalve, inequilateral, a little inflated, broad and oblique-oval in shape, opisthocline, extended anteroventrally; umbo not prominent, a little salient above the hinge margin; apical angle about 110°; umbonal angle about 80°, no umbonal ridge; umbo situated near the middle of the straight hinge margin; height slightly less than the length; both auricles obtuse-triangular, anterior one

Table 8. Measurements of *Palaeolima nakamurai* sp. nov. A : umbonal angle (angle between hinge line and longest axis of the shell)

Reg.	no.	L	H	H/L	U	U/L	a	A	r	r_1	V	Hor.
HP	100096	31.0	29.7	0.96	18.8	1.65	80	110	33	15	R	F 7-1
HP	100097	24+	24.5	—	—	—	80	110	30	16	R	AP 6

depressed, obscurely defined from the main body ; posterior one marked off anteriorly by a steep umbonal slope ; surface ornamented with 15-16 broadly rounded, primary radial ribs wider than interstitials, increasing in number by bifurcation, reaching 30 or more in total ; growth lines weak ; anterior auricle nearly smooth ; posterior one sculptured by weak radial costae ; hinge not preserved.

Comparison.—The species is similar in ornament to *Palaeolima simplex* Hind (1903, p. 39, pl. 39, figs. 24-27) from the Carboniferous of England, *P. petaline* Zhang (1981, p. 213, pl. 11, figs. 17) and *P. fasciculicostata* Liu (1976, p. 236, pl. 17, figs. 22, 24, 25), both from the lower Upper Permian of South China. It is distinguished from them by its larger size and more circular outline. *Palaeolima krotowi* (Stuckenberg, 1898, p. 336, pl. 1, fig. 29) from the Upper Carboniferous of Russia has radial ribs narrower than its interstitial furrows and is easily distinguished from the present species. Specimens referred to *P. krotowi* by Licharew (1927, p. 37, pl. 3, figs. 8-12, 14) and Muromtseva (1984, p. 79, pl. 33, fig. 11), from the Lower Permian of the Urals and Pechora, have broader radials than interstices, so the specific identification is doubtful. These shells are more similar to the present new species than to *P. krotowi*, but they differ from it being more anteroventrally extended and more oblique in shape.

Occurrence.—Rare in black shale of the lower part of the Hovtinden Member at Festningen (F 7-1) and at Ahlstrandodden (AP 6).

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