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WAAGENOCONCHA (BRACHIOPODA) FROM THE PERMIAN OF THE SOUTHERN KITAKAMI MOUNTAINS, NORTHEAST JAPAN

by

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(With 2 Tables, 3 Text-figures and 4 Plates)

(Contribution from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 1374)

Introduction

Among the large collection of fossils from the Permian deposits of the Southern Kitakami Mountains, some Waagenoconchid brachiopods have attracted the attention of paleontologists, since MINATO (1956, p.9) first reported the occurrence of them briefly. His materials were collected in those days by himself, and by Drs. H. TAKEDA, K. NAKAMURA and Mr. T. MAEKAWA from various localities in Kamiyasse, Kesen-numa City, Miyagi Prefecture, and Imo, Rikuzentakada City, Iwate Prefecture, and they have been long remained undescribed.

During his recent field works on the same region, the present author also collected a lot of specimens belonging to the genus *Waagenoconcha* from the two horizons: the lower part of the Lower Sakamotozawa series (=*Pseudoschwagerina* zone), and the upper part of the Lower Kanokura series (=*Parafusulina – Neoschwagerina* zone) (MINATO et al., 1964, p.830; TAZAWA, 1973, p.679).

All these new and old collections of Waagenoconchids have been studied by the writer in detail and the presence of the following three species is now made clear. They may be listed below: *Waagenoconcha asiatica* ZAVODOWSKY, *W. humboldti* (d'ORBIGNY), and *W. imperfecta* PRENDERGAST. Of them *W. asiatica* was collected from the *Pseudoschwagerina* horizon, and the latter two were obtained from the *Parafusulina – Neoschwagerina* horizon.

Genus Waagenoconcha

The genus *Waagenoconcha* CHAO (1927) is now placed by MUIR-WOOD and COOPER, (1960, p.252) in the subfamily Waagenoconchinae MUIR-WOOD and

COOPER, 1960. The genus widely distributed world over in the Carboniferous and the Permian.

Waagenoconcha was originally proposed by CHAO (1927, p.85) as a subgenus of *Productus* SOWERBY, 1814, of which *Productus humboldti* d'ORBIGNY is the type species. Although most subsequent authors raised it as a genus without further comment, critical remarks for the present genus were given by SOKOLSKAJA (1948, p.137), SARYTCHEVA and SOKOLSKAJA (1952, p.97), CAMPBELL (1956, p.469), COLEMAN (1957, p.82), MUIR-WOOD and COOPER (1960, p.252), and SARYTCHEVA (1968, p.103).

Waagenoconcha may be characteristic in having moderately convex pedicle valve with median sulcus, and the nearly flat, often geniculated brachial valve. The surface sculpture of both valves are composed of numerous, quincuncially arranged tubercles bearing long, fine spines, and weak, rarely strongly accentuated concentric rugae. Internally, it has the trifid cardinal process with long shaft, the dendritic adductor scars, but no brachial ridges.

The systematic position of *Waagenoconcha* is enumerated below:

Order Strophomenida ÖPIK, 1934
Suborder Productidina WAAGEN, 1883
Superfamily Productacea GRAY, 1840
Family Echinoconchidae STEHLI, 1954
Subfamily Waagenoconchinae MUIR-WOOD and COOPER, 1960
Genus ***Waagenoconcha*** CHAO, 1927

The following twenty-one species may be placed into the present genus: *Productus humboldti* d'ORBIGNY, 1842, *P. purdoni* DAVIDSON, 1862, *P. payeri* TOULA, 1874, *P. abichi* WAAGEN, 1884, *P. waageni* ROTHPLETZ, 1892, *P. irginae* STUCKENBERG, 1898, *P. silveanus* STUCKENBERG, 1898, *P. montpelierensis* GIRTY, 1910, *P.* (*Waagenoconcha*)' *vagans* REED, 1931, *Waagenoconcha imperfecta* PRENDERGAST, 1935, *Ruthenia wimani* FREDERICKS, 1934, *P.* (*W.*) *irginaeformis* STEPANOV, 1937, *P.* (*W.*) *gangeticus* var. *piassiaensis* EINOR, 1939, *W. krapivensis* SOKOLSKAJA, 1948, *W. delicatula* CAMPBELL, 1956, *Buxtonia sarytchevae* BENEDICTOVA, 1962, *W. abunakensis* SESTINI, 1966, *W. asiatica* ZAVODOWSKY, 1968, *W. balkhashensis* NASIKANOVA, 1968, *W. skinderi* SARYTCHEVA, 1968, and *W. obiensis* BENEDICTOVA, 1973.

They occur from the Tournaisian to Dzhulfian formations, but are most prolific in the Upper Carboniferous and the Lower Permian deposits. Geographically the genus has been known from Bolivia, Peru, Western U.S.A., Northwestern Canada, Spitzbergen, Greenland, Various parts of the U.S.S.R., Mongolia, South China, Japan, India, Pakistan, Iran, Timor, and West Australia.

Concerning to the paleoecology of *Waagenoconcha*, a detailed research was carried out by GRANT, (1966). He reconstructed a life habit of *Waagenoconcha abichi* (WAAGEN) using a suit of excellently silicified specimens collected from the top of the Middle Productus Limestone, Khisor Range, West Pakistan. In connection to the present study, the most interesting conclusion given by GRANT (1966, p.1068) is that the adult shell of this species may have lived free on the soft mud substrate, acting the dense long spines of the pedicle valve as roots or anchors. Although the Kitakami specimens of *Waagenoconcha* are not well preserved to retain spines, they are usually found in very fine-grained sediments as in the Pakistani spcimens.

Description of species

Waagenoconcha asiatica ZAVODOWSKY, 1968

P1.1, fig.1; P1.4, fig.5

1970 *Waagenoconcha asiatica*, ZAVODOWSKY, p.89, p1.3, figs.1, 2.

Material. —— Only a specimen, represented by both internal and external moulds of a pedicle valve, collected by the present author at Minokera-zawa, a tributary of Hosoo-zawa: UHR19848 (KF57A).

Diagnosis. —— *Waagenoconcha* species, small to medium in size, having slightly inflated pedicle valve with rather large ears and very shallow median sulcus.

Description. —— Shell small in size, subquadrate in outline, width 20 mm, length 16 mm; hinge-line straight, slightly shorter than the maximum width which is measured at the mid length of the valve; beak small, slightly overhanging the hinge-line; ears moderately developed, flattened, clearly marked off from visceral disk.

Pedicle valve weakly inflated with the maximum convexity at the umbo; median sulcus very shallow and broad at anterior half.

The surface of pedicle valve is ornamented by numerous, fine, quincuncially arranged tubercles and a few slender concentric rugae; tubercles elongated, becoming small and equidimensional-form on the ears, 3 to 4 tubercles per 5 mm length, 6 to 7 tubercles per 5 mm width at the middle portion of the valve.

Remarks. —— This species was originally described by ZAVODOWSKY in 1968. However, the writer could not refer the original paper. Nevertheless, the Kitakami material resembles well the specimens figured by the same author as

Waagenoconcha asiatica ZAVODOWSKY in another later published paper (ZAVODOWSKY, 1970). The latter were obtained from the Lower Permian (Asserian) of Siberia.

Both of them are small in size, and have slightly inflated pedicle valve, rather large ears, and faintly depressed median sulcus.

Comparison. —— In the shell outline *Waagenoconcha asiatica* ZAVODOWSKY is similar to *Waagenoconcha abichi* (WAAGEN), but the former differs from the latter in having more delicate ornamentation.

Occurrence. —— This material was obtained from the cropping-out of white-brown fine-grained sandstone at the mouth of small stream named Minokera-zawa, a branch of Hosoo-zawa, in association with many casts of brachiopods and bryozoans. The horizon of the sandstone bed is considered to be the lower part of the Lower Sakamotozawa series (TAZAWA, 1973, p.679).

Distribution. —— Burgarian horizon (Asselian), Popovka River, Siberia; Lower part of the Lower Sakamotozawa series of the Southern Kitakami Mountains, Northeast Japan (Text-fig.1).

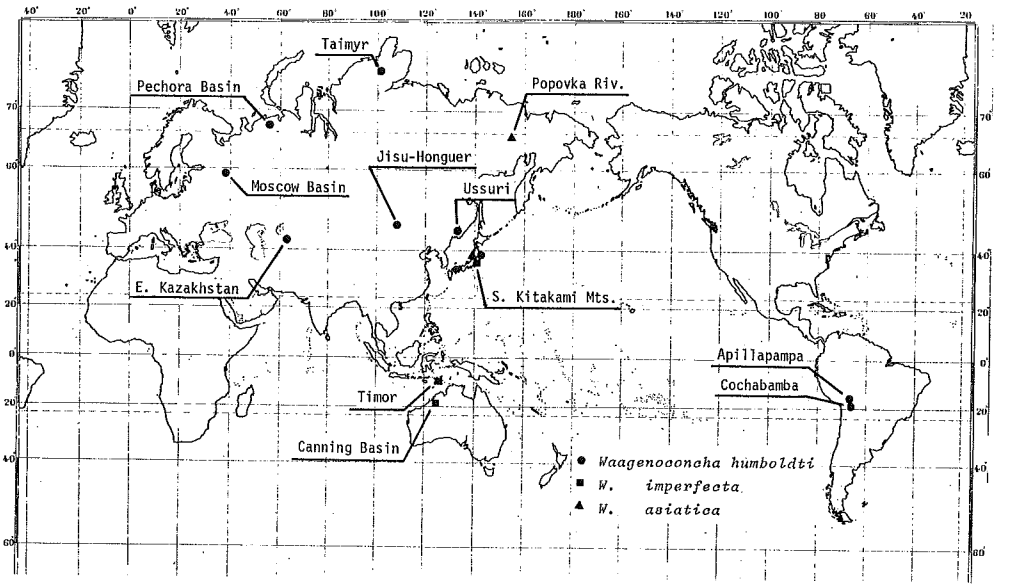


Fig. 1 Geographic distribution of the three species of *Waagenoconcha: W. humboldti* (d'ORBIGNY), *W. imperfecta* PRENDERGAST, and *W. asiatica* ZAVODOWSKY.

Waagenoconcha humboldti (d'ORBIGNY, 1842)

P1.1, figs. 2,3; Pl.2, fig.1; P1.4, fig.6.

1914 *Productus humboldti,* KOZLOWSKI, p.40, pl.7, figs.7-9
1925 *Productus humboldti,* FREDERICKS, p.19, pl.2, fig.84
1927 *Waagenoconcha humboldti,* CHAO, p.86, pl.15, figs.2,3.
1931 *Productus (Waagenoconcha) humboldti,* GRABAU, p.298, p1.29, figs.2,3.
1952 *Waagenoconcha humboldti,* SARYTCHEVA and SOKOLSKAJA, p.98, pl.15, fig.109
1956 *Waagenoconcha humboldti,* MINATO, p.9, listed only.
1960 *Waagenoconcha humboldti,* MUIR-WOOD and COOPER, p.252, p1.89, figs.6-10.
1963 *Waagenoconcha humboldti,* USTRITSKY and TSCHERNYAK, p.79, p1.6, figs.8,9.
1968 *Waagenoconcha humboldti,* SARYTCHEVA, p.107, p1.9, figs.5,6.
1972 *Waagenoconcha humboldti,* IFANOVA, p.102, p1.3, figs.11-13.

Type. —— Hypotype (*fide* MUIR-WOOD and Cooper, 1960): USNM 124074, Permian (Wolfcampian), Apillapampa, Cochabamba, Province of Capinota, Bolivia.

Material. —— The following three specimens from Imo-sawa are referred to this species: (1) UHR12595, (2) UHR12596, these two are represented by external moulds of pedicle valve, collected by Dr. K. NAKAMURA, (2) UHR19847 (KF124-2), external and internal moulds of a pedicle valve, rather badly deformed, collected by the present author.

Diagnosis. —— *Waagenoconcha* species, medium in size, wider subquadrate in outline, sculptured by rather coarse, elongated tubercles and a few weak concentric rugae.

Description. —— Dimensions are as follows (in mm).

	12595	12596
length	28	30
width	40	45
surface measure of pedicle valve	35	46
hinge width	36	41

Shell medium in size, wider, subquadrate in outline with the widest part at the middle; hinge-line straight, slightly shorter than the greatest width of the shell; beak small, overhanging the hinge-line a little; ears rather small, obscurely demarcated from visceral disc.

Pedicle valve moderately and evenly convex with rather broad and shallow sulcus; median sulcus deepened at middle portion, but less well defined

anteriorly.

Surface sculpture consists of numerous tubercles and a few weak concentric rugae; tubercles rather coarse and elongated, regularly arranged in quincunx, tapering to fine and rounded shape on the ears and near the anterior margin, 2 tubercles occupying a space of 5 mm length and 4 to 5 tubercles in 5 mm width at the middle portion of the pedicle valve (UHR12595).

Remarks. — This species was originally described by d'ORBIGNY (1842) from Yarbichambi, Bolivia as a new species of *Productus,* although, the present author could not refer it.

The outline of shell and the surface sculpture of the present materials are quite similar to those of *Waagenoconcha humboldti* (d'ORBIGNY) illustrated by CHAO (1927), SARYTCHEVA and SOKOLSKAJA (1952), MUIR-WOOD and COOPER (1960), USTRITSKY and TSCHERNYAK (1963), SARYTCHEVA (1968), and IFANOVA (1972). Of them, CHAO's specimens collected from Jisu-Honguer, Mongolia are re-described by GRABAU (1931) as *Productus* (*Waagenoconcha*) *humboldti* d'ORBIGNY.

In addition, the Kitakami specimens look like to the Waagenoconchids figured by KOZLOWSKI (1914) and FREDERICKS (1925) as *Productus humbolti* d'ORBIGNY.

"Productus humboldti" described by DAVIDSON (1862, p.32, pl.2, fig.6) and by WAAGEN (1884, p.695, pl.76, figs.1-3) from the Salt Range, are, however, not identical with the present species; the DAVIDSON's specimens appears to be *Waagenoconcha abichi* (WAAGEN), and the WAAGEN's materials are referable to *Waagenoconcha waageni* (ROTHPLETZ).

GRABAU also described and figured two specimens from Kweichow under the name of *Waagenoconcha humboldti* (d'ORBIGNY) (GRABAU, 1936, p.149, pl.14, figs.2,3). But they may be not conspecific with the species now in concern, because of the different surface sculpture.

Although NEWELL et al. (1953, p.86) mentioned the occurrence of *Waagenoconcha humboldti* (d'ORBIGNY) from the Lower Permian of Peru, their specimens were not illustrated, so the writer is not certain as to their identification.

Comparison. — *Waagenoconcha humboldti* (d'ORBIGNY) resembles well *Waagenoconcha montpelierensis* (GIRTY), in the outline of shell and the surface ornamentation. But *Waagenoconcha montpelierensis* is rather small in size, and the surface sculpture of it appears to be on a finer scale.

In apperance, *Waagenoconcha abichi* (WAAGEN) is also akin to the present species. However, the shell surface of the former is ornamented by more coarser tubercles.

A similar form, *Waagenoconcha irginae* (STUCKENBERG) is distinguished from

Waagenoconcha humboldti (d'ORBIGNY) by the short hinge-line, and the fine, more closely arranged tubercles.

Occurrence. — At Imo-sawa, these three specimens were preserved in two boulders of greenish brown-coloured fine-grained sandstone, which presumably derived from the sandstone beds of the upper part of the Lower Kanokura series developed in the upper course of this tributary. Numerous impressions of brachiopods, bryozoans, and crinoids are found in association.

Distribution. — Lower Permian (Wolfcampian) of Bolivia; Upper Carboniferous of Moscow Basin, U.S.S.R.; Upper Carboniferous to Lower Permian of East Kazakhstan, Taimyr, and Ussuri, U.S.S.R.; Talatinskaja formation and Lekvorkutskaja formation of Pechora Basin, U.S.S.R.; Jisuhonguer Limestone of Jisu-Honguer, Mongolia; Upper part of the Lower Kanokura series of the Southern Kitakami Mountains, Northeast Japan (Text-fig.1).

Waagenoconcha imperfecta PRENDERGAST, 1935

P1.1, figs.4-6; P1.2, figs.2-7; P1.3, figs.1-3;
P1.4, figs.1-4,7.

1916 *Products waageni,* BROILI, p.14, pl.68 (4), figs.1,3-5 (excl. fig.2).
1928 *Productus purdoni,* HAMLET, p.23, pl.4, figs.1a-c; pl.5, figs.1a,b.
1935 *Waagenoconcha imperfecta,* PRENDERGAST, p.15, pl.4, figs.1-3.
1943 *Waagenoconcha imperfecta,* PRENDERGAST, p.25, pl.3, figs.7-9.
1943 *Waagenoconcha vagans,* PRENDERGAST, p.26, pl.3, fig.6.
1957 *Waagenoconcha imperfecta,* COLEMAN, p.82, pl.10, figs.8-14; pl.11, figs.1-6.

Type. — Holotype: UWA3044, Liveringa formation, West Kimberley, Western Australia. Allotypes (*fide* PRENDERGAST, 1935): UWA2768, 2775, same horizon and locality. Homeotypes (*fide* COLEMAN, 1957): UWA27457, Liveringa formation, Mt. Hardman, West Kimberley. UWA20454, Liveringa formation, Mt. Cedric, West Kimberley.

Material. — Fifty-four specimens showing external and internal features, variously preserved. Of these, fifteen were collected by Mr. T. MAEKAWA at Hosoo-zawa: UHR12010, 12013, 12014, 12015, 12017, 12018, 12019, 12020, 12023, 12030, 12032, 12036, 12040, 12041, 12134; two specimens, by Drs. H. TAKEDA and K. NAKAMURA at Hosoo-zawa: UHR12132, 12137; a specimen by Dr. K. NAKAMURA at Imo-sawa: UHR19810; all the other specimens were collected by the present author at Kidono-sawa, a tributary of Shigeji-sawa: UHR19812 (KF11D-1) – 19817 (KF11C-2); at Nidano-sawa, a branch of Shigeji-sawa: 19818 (KF48), 19820 (S111210) – 19841 (S111209); at

Imo-sawa: 19811 (KF124-1), 19819 (KF121-1), 19843 (KF121-2) – 19846 (KF124-3); at Isozumi-sawa: 19842 (KF115).

Diagnosis. —— *Waagenoconcha* species, characterized by the presence of accentuated concentric rugae, and the fineness of the spinose ornamentation.

Description. —— The following dimensions give an approximation of typical specimens of this species (in mm).

	12132	19810	19813	19816	19818	19825
length	56	48	57	9	43	25
width	34	40	41	12	42	38
height	21	22	20	4	16	15
surface measure of pedicle valve	85	88	71	11	71	30
hinge width	28	35	33	7	32	32

Shell large in size, longer than wide; hinge-line straight, not exceeding the greatest width which is measured at two-thirds of the length from the beak; beak large, strongly incurved and overhanging the hinge-line; ears very small or absent.

Pedicle valve moderately convex in lateral profile with the greatest convexity at the umbo, whereas transversely highly elevated with very steep flanks; median sulcus rather deep, commencing at the extremity of the beak and dividing the valve into two parts entirely. Brachial valve nearly flat at visceral disc with weak median fold, strongly geniculated and upturned anterolaterally; trail long, 10 to 22 mm in gerontic specimens.

Concentric rugae strongly but irregularly developed on pedicle valve, rather weak on brachial valve. Numerous, fine tubercles closely and regularly arranged in quincunx on both valves which may be interesecting semicircles. They are enumerated in an adult specimen (UHR19818), 3 to 4 tubercles per 5 mm length and 8 to 9 per 5 mm width at the middle portion of the pedicle valve.

Interior of pedicle valve with obscure dendritic adductor scars separated by median sulcus. Adductor platforms narrow and elongate, 2.3 mm in width, 17 mm in length (UHR19813); diductor scars longitudinally striate, occupying the posterior half of the valve on either side of the adductor scars; coarse, irregular pustules around the anterior margin. Interior of brachial valve with trifid cardinal process on long and thick shaft; median septum strong, extending about two-thirds the length of the valve, joinning to semicircular platforms which located posteriorly; numerous, fine pustules cover the internal surface of the valve which become coarse anteriorly.

Remarks. — The holotype of this species figured by PRENDERGAST (1935, pl.4, fig.2) is an exfoliated pedicle valve, so the surface sculpture of it is unknown. However, one of the syntypes, an external mould of brachial valve illustrated in figure 1 of the same plate shows well very fine tubercles which are regularly arranged in quincunx. Afterwards, he (PRENDERGAST, 1943) and COLEMAN (1957) described and figured many specimens of the present form from Western Australia.

The present specimens now under discussion are quite similar to these Australian specimens in the surface ornamentation and the outline of shell.

The Timorian specimens figured by BROILI (1916) as *Productus waageni* ROTHPLETZ, and by HAMLET (1928) as *Productus purdoni* DAVIDSON seem to be conspecific with the present form, because of their fine, quincuncially arranged

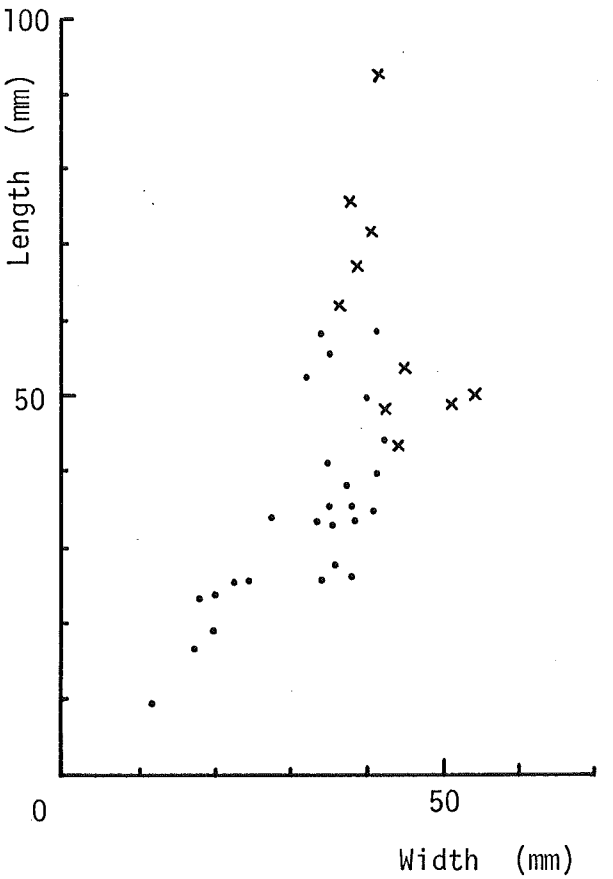


Fig. 2 Relation between the length and the width of the shell of *Waagenoconcha imperfecta* PRENDERGAST, Solid circles represent the measurements of the specimens from the Southern Kitakami Mountains. Crosses, the Australian and Timorian specimens (after BROILI, 1916, PRENDERGAST, 1935, and COLEMAN, 1957).

tubercles; whereas one of the BROILI's materials (pl.68 (4), fig.2) is eliminated from the present species in having rather coarse tubercles.

As COLEMAN (1957, p.84) mentioned in his description of *Waagenoconcha imperfecta* PRENDERGAST, the present materials from the Kitakami Mountains also show considerable variation in the shell outline. After careful study on them and consideration for the measurements of the aforesaid Australian and the Timorian specimens, the writer arrived at the conclusion that the bulk of the Japanese specimens are represented by younger shells, and in the present species, a considerable transformation is caused through its ontogeny on the shell outline. More precisely, a wider or equidimensional shell-formed young individual of *Waagenoconcha imperfecta* abruptly accelerats to grow in longitudinal direction when it attained to a certain size, about 35 mm in width. With greater the length, the beak becomes incurved and the brachial valve bent up anteriorly. Accordingly, the gerontic material of the present species shows longitudinally oval shell with strongly incurved beak and steeply geniculated brachial valve. The variation of the ratio of the shell-length to the shell-width of *Waagenoconcha imperfecta* is given in Text-fig.2, and the shell outline in some stages is diagramatically shown in Text-fig.3.

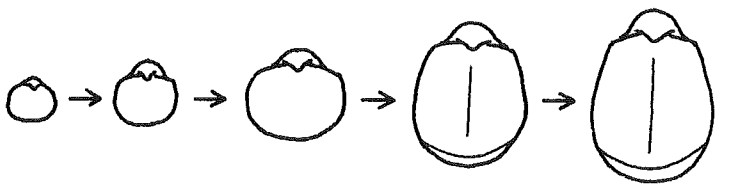


Fig. 3 Ontogenic change in the shell outline of *Waagenoconcha imperfecta* PRENDERGAST.

Comparison. — In the outline of shell, *Waagenoconcha imperfecta* PRENDERGAST resembles *Waagenoconcha payeri* (TOULA), but the latter lacks strongly developed concentric rugae, and is ornamented by more coarser tubercles.

Waagenoconcha purdoni (DAVIDSON) also resembles *Waagenoconcha imperfecta* PRENDERGAST. However, it differs from the latter in having very short and slightly arched hinge-line, smaller beak, and in lacking accentuated concentric rugae.

Waagenoconcha abunakensis SESTINI shows similar ornamentation, but the shell is transversely broad, and the beak is not so strongly overhanging the hinge-line.

Occurrence. — Most of the specimens now at hand were obtained from the cropping-outs of dark grey calcareous fine-grained sandstone at Kidono-sawa

and greyish brown fine-grained sandstone at Nidano-sawa, which belong to the upper part of the Lower Kanokura series (TAZAWA, 1973, p.679). In both cases, they aggregated densely in the sandstone together with fragments of crinoid oscicles. Brachiopod remains of any other different taxa are almost lacking, except for a few casts of *Spiriferellina cristata* (SCHLOTHEIM) accompanied at the latter exposure.

Distribution. —— Liveringa formation of Kimberley, Western Australia; Permian of Timor; Upper part of the Lower Kanokura series, the Southern Kitakami Mountains, Northeast Japan (Text-fig.1).

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(Manuscript received on May 13, 1974)

PLATES 1 ~ 4 AND EXPLANATION

Explanation of Plate 1

(All figures are in natural size)

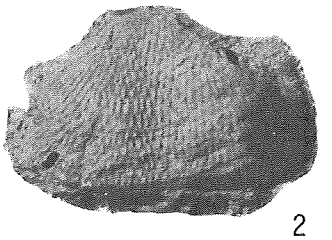
Fig. 1. *Waagenoconcha asiatica* ZAVODOWSKY
ventral view of pedicle valve: UHR19848 (KF57A).

Figs. 2,3. *Waagenoconcha humboldti* (d'ORBIGNY)
2. ventral view of pedicle valve: UHR12595.
3. ventral view of pedicle valve: UHR19847 (KF124-2).

Figs. 4-6. *Waagenoconcha imperfecta* PRENDERGAST,
4a,b,c,d. ventral, posterior, anterior, and lateral views of pedicle valve: UHR19828 (KF9F-4).
5a. dorsal view of brachial valve: 5b. interior of brachial valve: UHR19831 (KF9F-7).
6a. ventral view of pedicle valve: 6c. dorsal view of brachial valve: 6b,d,e,f,g. ventral, dorsal, posterior, anterior, and lateral views of "Steinkern": UHR19813 (KF11B-1).



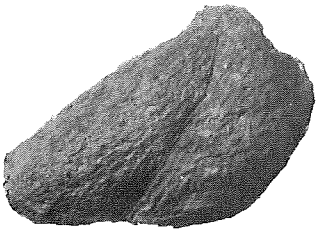
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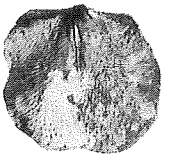
2



5a



3



5b



4a



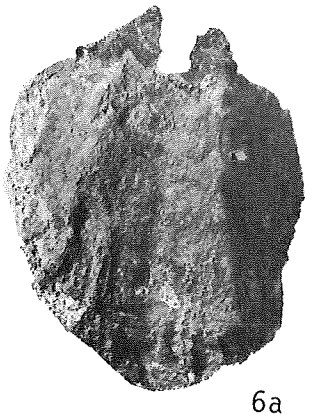
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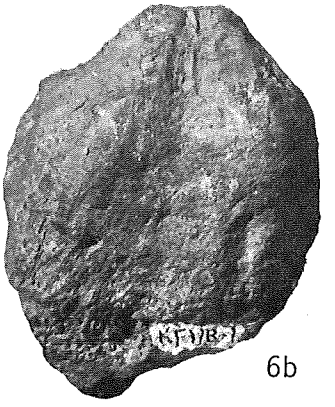
4c



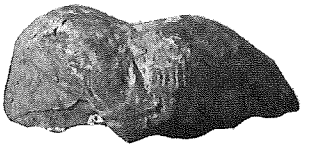
4b



6a



6b



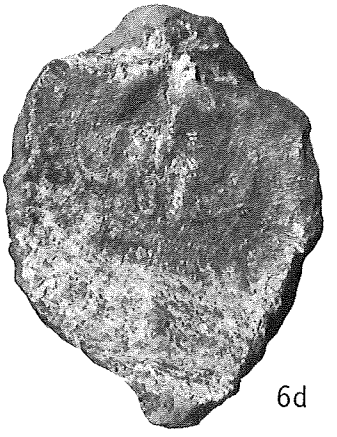
6e



6f



6c



6d

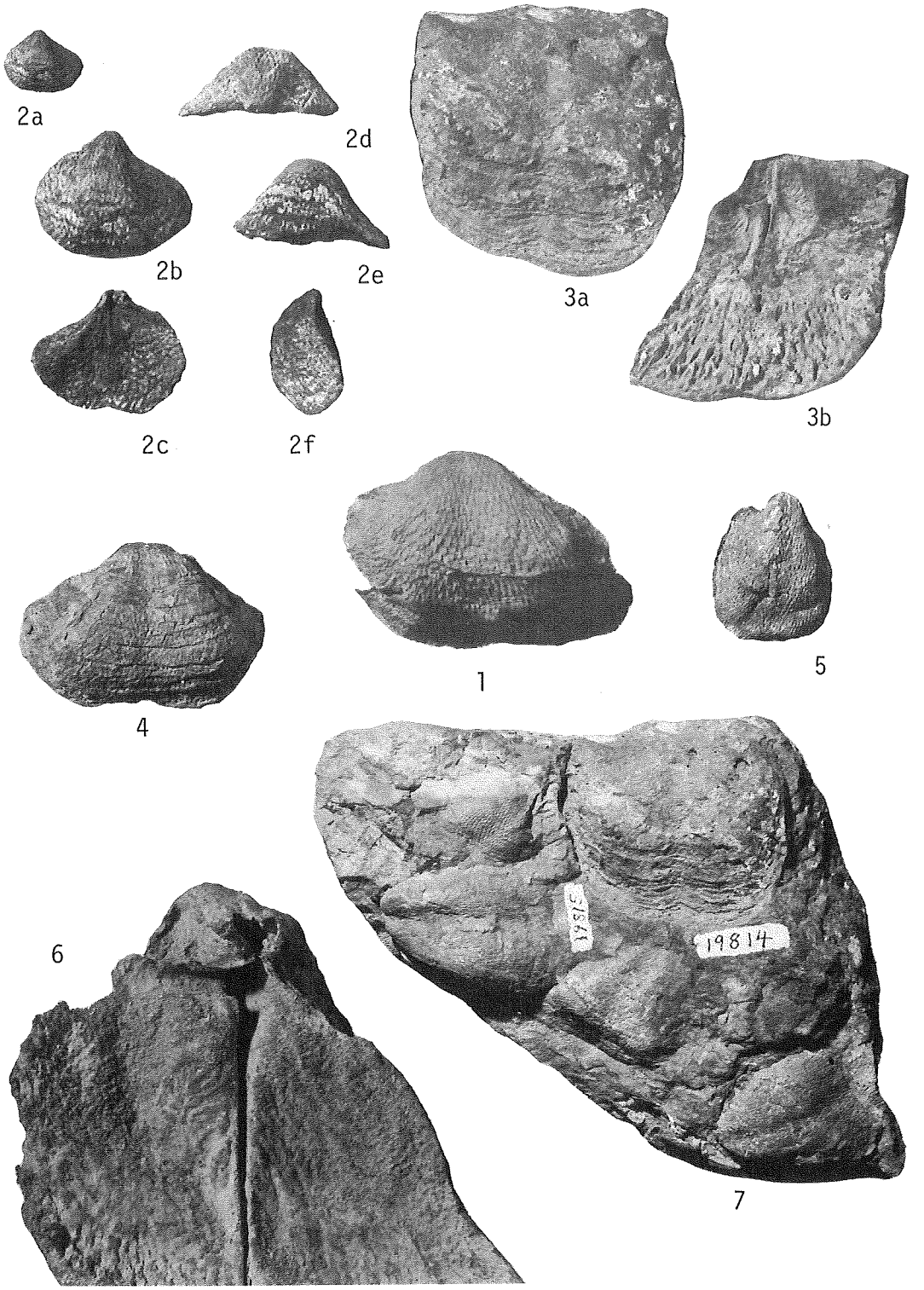


6g

Explanation of Plate 2

Fig. 1. *Waagenoconcha humboldti* (d'ORBIGNY)
ventral view of pedicle valve (nat. size): UHR12596.

Figs. 2-7. *Waagenoconcha imperfecta* PRENDERGAST.
2a. ventral view of "Steinkern" (nat. size): 2b,c,d,e,f, ventral, dorsal, posterior, anterior, and lateral views of "Steinkern" (X2): UHR19816 (KF11-1).
3a,b. exterior and interior of brachial valve (nat. size): UHR19814 (KF11D-2).
4. ventral view of pedicle valve (nat. size): UHR19825 (KF9B-5).
5. ventral view of pedicle valve (nat. size): UHR19812 (KF11D-1).
6. interior of brachial valve, showing trifid cardinal process, strongly developed median septum, and dendritic adductor scars (X2): UHR19819 (KF121-1).
7. block crowded with mainly pedicle valve (X3/4): including the two specimens, UHR19814 and UHR19815.


2a
2d
2b
2e
3a
3b
2c
2f
1
5
4
6
19814
7

Explanation of Plate 3

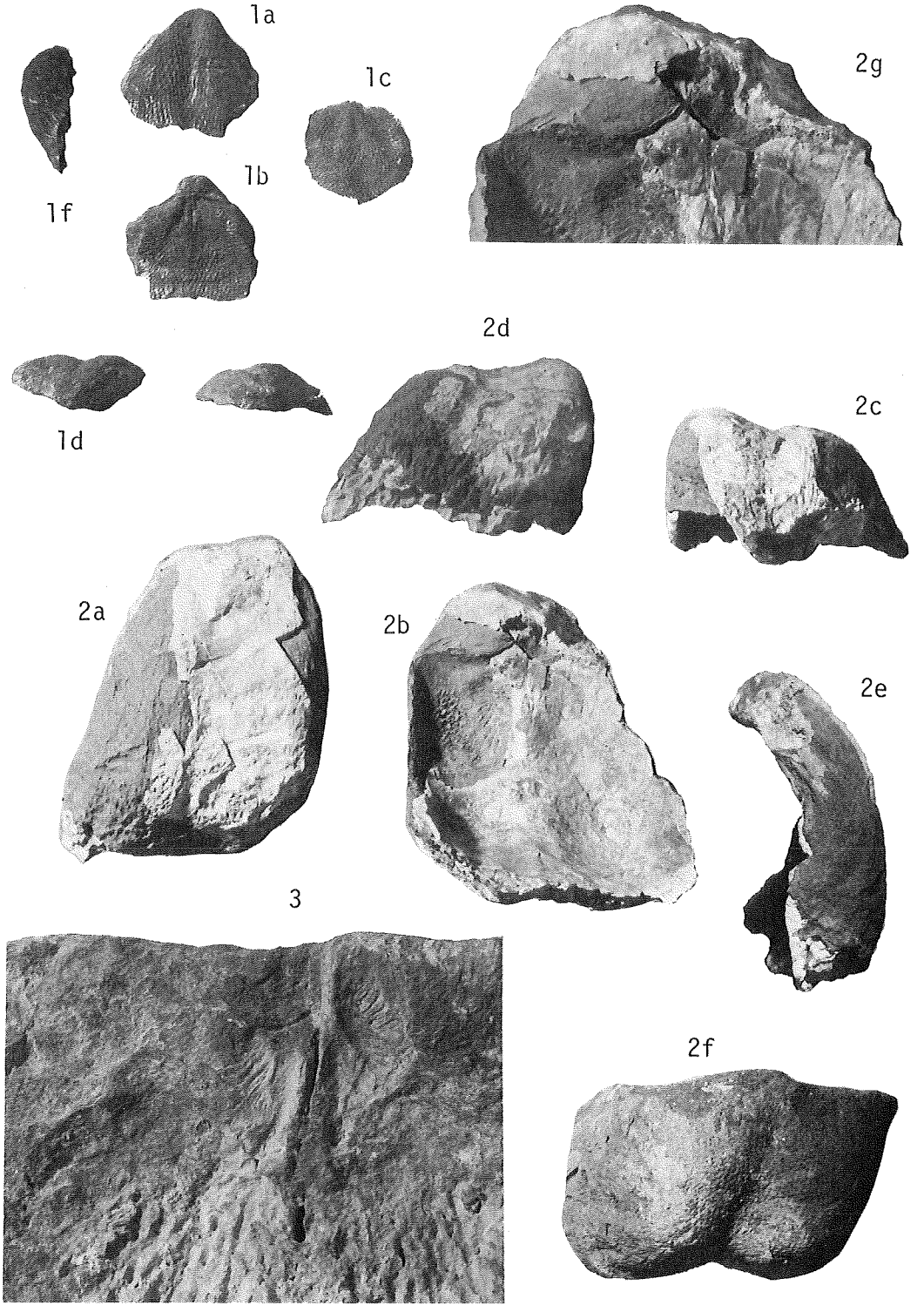
(All figures are in natural size, except Figs. 2g,3)

Figs. 1-3. *Waagenoconcha imperfecta* PRENDERGAST.

1a,b,d,e,f, ventral, dorsal, posterior, anterior, and lateral views of "Steinkern"; 1c. dorsal view of brachial valve: UHR19817 (KF11C-2).

2a,b,c,d,e. ventral, dorsal, posterior, anterior, and lateral views of "Steinkern"; 2f. dorsal view of brachial valve: 2g. a part of the interior of brachial valve, showing trifid cardinal process (X2): UHR19810.

3. a part of the interior of brachial valve, showing dendritic adductor scars (X2): UHR19814 (KF11D-2).


1a
1c
2g
1b
1f
2d
1d
2c
2a
2b
2e
3
2f

Explanation of Plate 4

Figs. 1-4,7. *Waagenoconcha imperfecta* PRENDERGAST

1a,b,c,d. ventral, posterior, anterior, and lateral views of pedicle valve (nat. size): UHR19818 (KF48).

2. dorsal view of brachial valve (nat. size): UHR19820 (S111210).

3. modering clay cast of pedicle valve (nat. size): UHR12137.

4. ventral view of pedicle valve (nat. size): UHR19815 (KF11D-3).

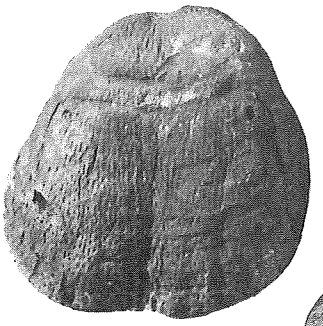
7. a part of the external surface of pedicle valve, showing very fine tubercles arranged in quincunx (X5): UHR19818 (KF48).

Fig. 5 *Waagenoconcha asiatica* ZAVODOWSKY

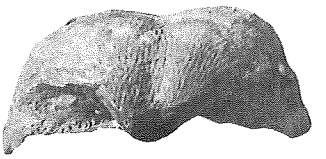
a part of the external surface of pedicle valve, showing quincuncially arranged tubercles (X5): UHR19848 (KF57A).

Fig. 6 *Waagenoconcha humboldti* (d'ORBIGNY)

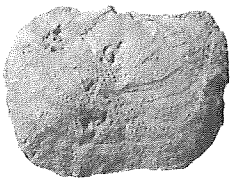
a part of the external surface of pedicle valve, showing elongated tubercles arranged in quincunx (X5): UHR12595.



1a



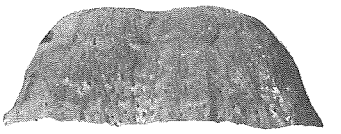
1b



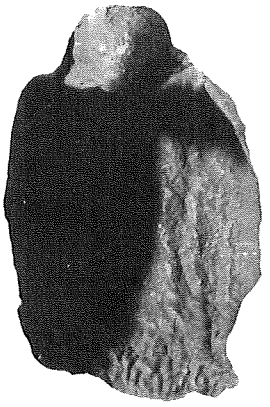
2



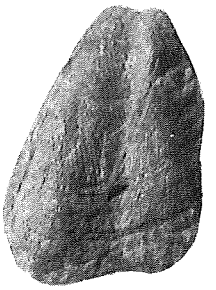
1d



1c

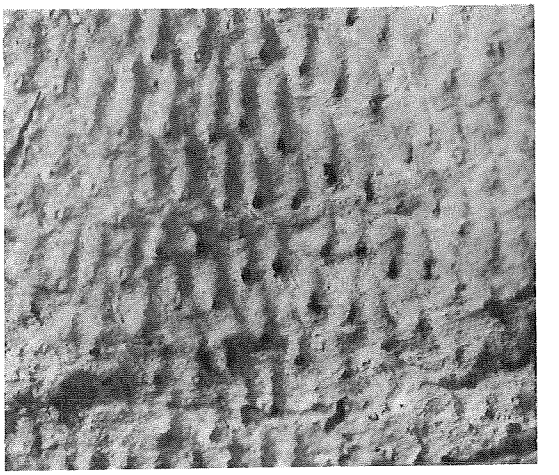


3

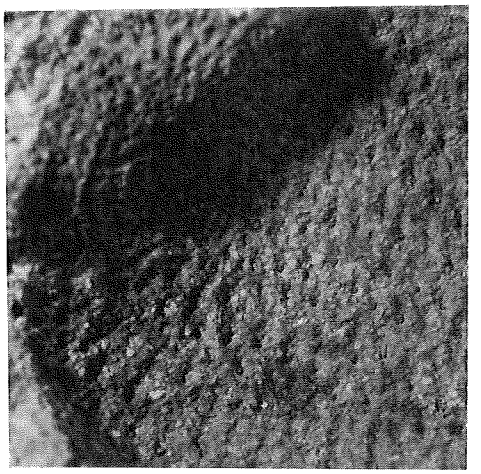


4

6



5



7

