Middle Permian brachiopods from Hiyomo, Mino Belt, central Japan: Their provincial relationships with North America

Jun-ichi TAZAWA* and Shuzhong SHEN**

Abstract

Thirteen brachiopod species belonging to twelve genera are described from a Middle Permian allochthonous basalt-limestone block of Hiyomo in the Nyukawa district, Mino Belt, central Japan. Among them, *Lepidospirifer miyakei* and *Anomaloria hiyomoensis* are new species. The Hiyomo fauna contains some Tethyan elements such as *Enteletes, Compressoproductus* and *Eolyttonia*, but lacks completely both the Boreal and Gondwanan elements, and closely resembles the Middle Permian (Leonardian to lower Guadalupian) brachiopod fauna of West Texas in generic and specific levels. The above data imply that the basalt-limestone block containing brachiopods was a part of a carbonate buildup on basaltic seamount at equatorial region of the Panthalassa, which probably connected zoogeographically with North America in Middle Permian.

Key words : Brachiopods, Middle Permian, Hiyomo, Mino Belt, Panthalassa

Introduction

The Middle Permian brachiopods described below were found and collected by Mr. Yukio Miyake of Miya-mura, Ono-gun, Gifu Prefecture, from reddish-purple tuffaceous limestone exposed at Ryomenkutsu, near Hiyomo, 15 km east of Takayama, i.e., the Nyukawa district, northern part of the Mino Belt, central Japan (Fig. 1). The tuffaceous limestone containing brachiopods is a part of a large (area of outcrop: 500m × 200 m) basalt-limestone block, an olistolith in the Jurassic mélange widely distributed in this district (Adachi and Kojima, 1983; Imazato and Otoh, 1993). Besides brachiopods, the tuffaceous limestone of Hiyomo contains numerous fossils of a fusulinid *Parafusulina yabei* Hanzawa, which indicates clearly the Middle Permian (Ufimian or Kubergandian) age.

---

* Department of Geology, Faculty of Science, Niigata University, Niigata 950-21, Japan.
** Research student: Graduate School of Science and Technology, Niigata University, Niigata 950-21, Japan; Department of Geology, China University of Mining and Technology, Xuzhou, Jiangsu 221008, P.R. China.
(Manuscript received 9 January, 1997, accepted 6 February, 1997)

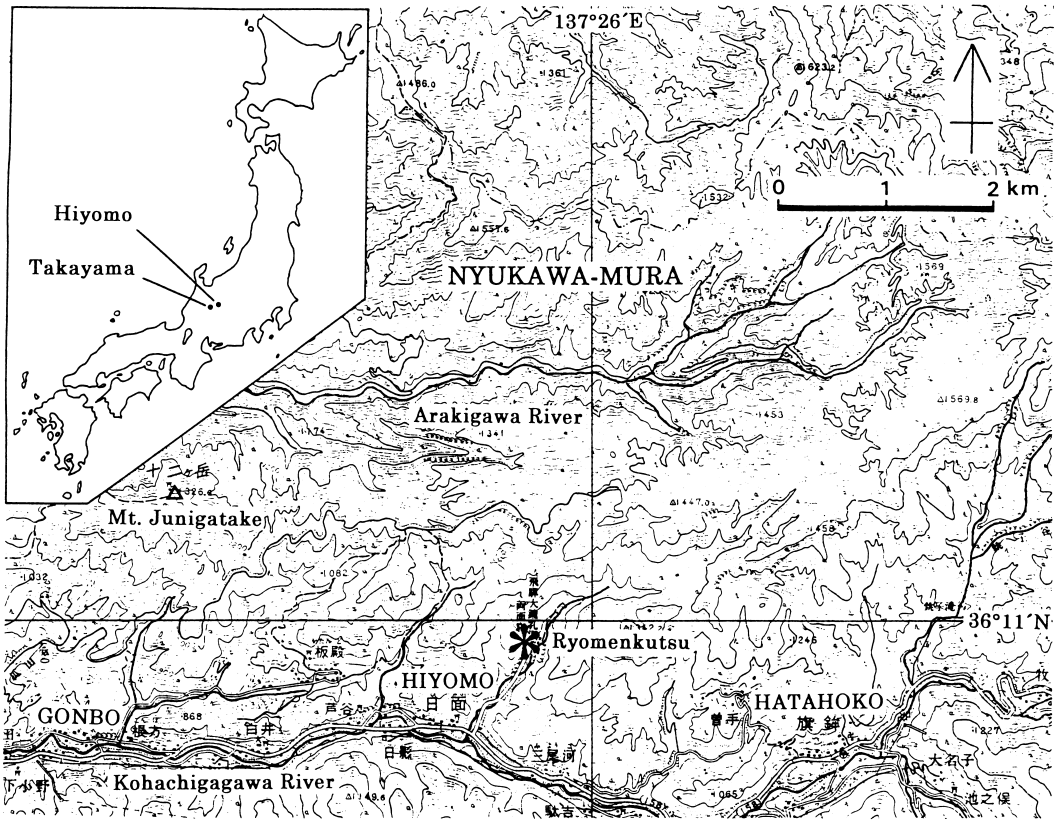

Fig. 1. Map showing the fossil locality (using the topographical map of "Funatsu" scale 1:50,000 publishedby Geographical Survey Institution of Japan).

Permian brachiopods from basalt-limestone blocks in the Mino Belt (s.s.) have been scarcely known except those of Akasaka, about 120 km southwest of Hiyomo. In the Akasaka district Sato (1919) found and reported firstly a lyttoniid brachiopod as the name of *Lyttonia richthofeni* Kayser from the Permian limestone block. Subsequently, Hayasaka (1925) listed the following six brachiopod species: *Lyttonia richthofeni* Kayser em. Hayasaka, *Scacchinella* sp., *Reticularia lineata* Martin, *Reticularia waageni* Loczy em. Frech, *Reticularia* cf. *inaequiateralis* Gemmellaro and *Terebratuloidea*? sp. Afterwards Ozawa (1927) listed and figured two species, *Enteletes akasakensis* Ozawa and *Lyttonia richthofeni* Kayser; and Hayasaka (1932) described three species, *Geyerella* sp., *Enteletes minoensis* Hayasaka and *Enteletes suessi* Schellwien.

The purpose of this paper is to describe the Middle Permian brachiopods from the basalt-limestone block of Hiyomo in the Mino Belt, and to discuss the biogeographic characters of this fauna. The brachiopod specimens are stored in the Department of Geology, Faculty of Science, Niigata University.

The Hiyomo fauna

The brachiopods of Hiyomo described here, and the number of specimens are shown as follows:

Enteletes sp.	1
Chonetinella cf. *costellata* Cooper and Grant	1
Ametoria cf. *residua* Cooper and Grant	1
Calliprotonia sp.	2
Compressoproductus sp.	1
Glyptosteges? sp.	1
Eolyttonia sp.	1
Cenorhynchia? sp.	1
*Martinia semiplana*Waagen	2
Martinia sp.	1
Cartorhium coristum Cooper and Grant	2
Lepidospirifer miyakei n. sp.	7
Anomaloria hiyomoensis n. sp.	18

Among these species, *Chonetinella* cf. *costellata*, *Ametoria* cf. *residua* and *Cartorhium coristum* are identical or comparable with the North American species, described by Cooper and Grant (1975, 1976a) from the Lower and Middle Permian (Wolfcampian and Leonardian) of West Texas. Genera such as *Glyptosteges*, *Cenorhynchia* and *Lepidospirifer* have hitherto been reported only from the Lower and Middle Permian (Wolfcampian to lower Guadalupian, mainly Leonardian) of North America (King, 1930; Cooper and Grant, 1969, 1975, 1976a; Mills and Langenheim, 1987). Moreover, the Hiyomo fauna has some typical Tethyan-type genera, *Enteletes*, *Compressoproductus* and *Eolyttonia*, but lacks both of the Boreal- and Gondwanan-type genera.

From these data we are convinced of strong relationships between the Middle Permian faunas of Hiyomo and North America, especially West Texas. This conclusion does not conflict with the palaeomagnetic data (Hattori and Hirooka, 1977, 1979; Hattori, 1982) and the sedimentological and palaeontological data (Ozawa, 1987; Sano and Kanmera, 1996), which show that the Permian basalt-limestone blocks in the Mino Belt originate oceanic buildups formed at low latitudinal area, probably the equatorial region of the Panthalassa in the Middle Permian time.

Description of Species

Order Orthida Schuchert and Cooper, 1932
Superfamily Enteletacea Waagen, 1884
Family Enteletidae Waagen, 1884
Subfamily Enteletinae Waagen, 1884
Genus *Enteletes* Fisher de Waldheim, 1825

Enteletes sp.
Pl. 1, figs. 1a, 1b.

Material.–One pedicle valve, NU-B71.

Remarks.–One fragment of pedicle valve, lacking the anterior half, is available. The posterior part of the pedicle valve is gently convex in lateral profile, but moderately and unevenly convex in anterior profile, with flattened venter and steep lateral slopes. The external ornament of the pedicle valve consists of strong radial plicae and numerous fine costellae, numbering 6 plicae at 15 mm anterior from the umbo. Internally the pedicle valve has a median septum of 8 mm long and two parallel dental plates, which are slightly shorter than the former.

The present specimen is safely assigned to the genus *Enteletes* on the basis of its external ornament and internal structure of the pedicle valve. The Hiyomo specimen is superficially resembles shells of *Enteletes tschernyscheffi* Diener (1897, p. 67, pl. 5, figs. 7-11) from the Middle Permian (Punjabian after Waterhouse, 1976) of Chitichun No. 1 in the Kumaon Himalayas, and also *Enteletes subcircularis* Cooper and Grant (1976b, p. 2640, pl. 675, figs. 36-39; pl. 676, figs. 1-30; pl. 685, figs. 1-27) from the Skinner Ranch, Hess and Bone Spring formations of West Texas. But the poor preservation of the present material makes accurate comparison difficult.

Order Chonetida Nalivkin, 1979
Suborder Chonetidina Muir-Wood, 1955
Superfamily Chonetacea Bronn, 1862
Family Rugosochonetidae Muir-Wood, 1962
Subfamily Chonetinellinae Muir-Wood, 1962
Genus *Chonetinella* Ramsbottom, 1952

Chonetinella cf. *costellata* Cooper and Grant, 1975
Pl. 1, figs. 2a, 2b.

Compare.–
1930 *Chonetes granulifer* Owen: King, p. 60, pl. 9, fig. 14.
1975 *Chonetinella costellata* Cooper and Grant, p. 1273, pl. 479, figs. 1-23.

Material.–One pedicle valve, NU-B72.

Description.–Shell large size for genus, wider than long, subrectangular in outline, widest at hinge line; length 8 mm, width 12 mm. Pedicle valve moderately convex in lateral profile, most convex near midvalve. Sulcus narrow and shallow, originating at umbo and extending to anterior margin of valve. Cardinal extremities blunt, acute. Ears large, slightly convex, and not obviously demarcated from visceral portion. External surface of pedicle valve ornamented by numerous, fine costellae, with a density of 7 per 1 mm near anterior margin, increasing by bifurcation and intercala-

tion on lateral slopes. Internal structure of pedicle valve unknown.

Remarks.–In size, shape and external ornament of pedicle valve, especially the presence of a narrow and shallow sulcus, the Hiyomo specimen closely resembles *Chonetinella costellata* Cooper and Grant, 1975, described and figured from the Gaptank and Neal Ranch formations of the Glass Mountains, West Texas (Cooper and Grant, 1975, p. 1273, pl. 479, figs. 1-23). But the accurate comparison is difficult for this poorly preserved specimen.

Order Productida Sarytcheva and Sokolskaja, 1959
Suborder Productidina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Productidae Gray, 1840
Subfamily Buxtoniinae Muir-Wood and Cooper, 1960
Genus *Ametoria* Cooper and Grant, 1975

Ametoria cf. *residua* Cooper and Grant, 1975
Pl. 1, figs. 3a, 3b.

Compare.–
1975 *Ametoria residua* Cooper and Grant, p. 1056, pl. 256, figs. 1-14.

Material.–One pedicle valve, NU-B73.

Description.–Shell medium size for genus, transversely subquadrate in outline, widest at hinge line; length 20 mm, width 24 mm. Pedicle valve strongly convex in lateral profile, with greatest convexity at posterior half; anterior profile strongly arched, with V-shaped trench at midvalve. Sulcus wide, deep, originating at umbo, rapidly widening and deepening anteriorly, and occupying about one-third of shell width near anterior margin. Ears small, but clearly demarcated from visceral portion. External surface densely spinose, two kinds of elongated spine bases, larger and smaller ones on visceral portion. Spine bases on ears not observed. Internal structure of pedicle valve unknown.

Remarks.–This specimen closely resembles the holotype (USNM153476) of *Ametoria residua* Cooper and Grant, 1975, figured by Cooper and Grant (1975, pl. 256, figs. 7-10) from the Road Canyon Formation of the Glass Mountains, West Texas in size, shape and external ornament of the pedicle valve. But the ears of the Hiyomo specimen are not well-preserved, so the accurate comparison between the two specimens is difficult.

Superfamily Echinoconchoidea Stehli, 1954
Family Echinoconchidae Stehli, 1954
Subfamily Echinoconchinae Stehli, 1954
Genus *Calliprotonia* Muir-Wood and Cooper, 1960

Calliprotonia sp.
Pl. 1, figs. 4a-4c.

Material.–Two brachial valves, NU-B74, 75.

Description.–Shell small size for genus; length of brachial valve 12 mm, width of brachial valve about 11 mm in a better preserved specimen (NU-B57). Brachial valve slightly concave in both of lateral and anterior profiles; fold absent; ears small and almost flattened. External surface of brachial valve ornamented by strongly and regularly developed concentric bands, numbering 4 in 5 mm on venter. Numerous fine spine bases occurring on each band. Internal structure of brachial valve unknown.

Remarks.–Externally the Hiyomo specimens resemble shells of *Calliprotonia* sp., described and figured by Cooper and Grant (1975, p. 1040, pl. 386, figs. 10-13; pl. 445, fig. 52) from the Neal Ranch Formation of the Glass Mountains, West Texas.

The type species, *Calliprotonia renfrarum* Muir-Wood and Cooper, 1960, from the Upper Pennsylvanian of north-central Texas (Muir-Wood and Cooper, 1960, p. 247, pl. 81, figs. 1-13) differs from the present species in its larger dimensions.

Superfamily Linoproductoidea Stehli, 1954
Family Monticuliferidae Muir-Wood and Cooper, 1960
Subfamily Compressoproductinae Jing and Hu, 1978
Genus *Compressoproductus* Sarytcheva, 1960

Compressoproductus sp.
Pl. 1, figs. 5a, 5b.

Material.–One pedicle valve, NU-B76.

Remarks.–The pedicle valve specimen of Hiyomo is lacking the posterior portion. However, this specimen is assigned to the genus *Compressoproductus* on the basis of its elongately triangular outline (length about 14 mm, width about 13 mm), and surface ornament of strong concentric rugae and very fine costellae on the whole valve; 3-4 rugae in 5 mm at the midvalve, 5 capillae in 1 mm near the anterior margin.

This specimen most resembles shells of *Compressoproductus acuminatus* Cooper and Grant (1975, p. 1204, pl. 462, figs. 9-53; pl. 463, figs. 9-11) from the Road Canyon Formation of the Glass Mountains, West Texas in size, shape and ornament of pedicle valve, but cannot assigned to the American species by the poor material.

The type species, *Compressoproductus compressus* (Waagen, 1884), originally described and figured by Waagen (1884, p. 710, pl. 81, figs. 1, 2) from the Wargal Formation of the Salt Range, Pakistan is clearly distinguished from the present species by its more flattened and larger pedicle valve.

Compressoproductus mongolicus (Diener, 1897, p. 28, pl. 4, figs. 8-10) from the Middle Permian

of Chitichun No. 1, Kumaon Himalayas differs from the Hiyomo species in having much wider pedicle valve.

Superfamily Aulostegoidea Muir-Wood and Cooper, 1960
Family Aulostegidae Muir-Wood and Cooper, 1960
Subfamily Chonosteginae Muir-Wood and Cooper, 1960
Genus *Glyptosteges* Cooper and Grant, 1975

Glyptosteges? sp.
Pl. 1, figs. 6a. 6b.

Material.–One pedicle valve, NU-B77.

Remarks.–The sole specimen from Hiyomo is lacking the posterolateral portion of the pedicle valve. This specimen may be assigned to the genus *Glyptosteges* by its small-sized (length about 9 mm, width about 13 mm) and strongly geniculated pedicle valve, ornamented by prominent, rounded costae and fine, wavy concentric striae on both of the visceral disc and trail. The costae are often bifurcating on the trail, numbering 5-6 in 5 mm at the anterior margin.

The Hiyomo specimen somewhat resembles shells of *Glyptosteges insculptus* Cooper and Grant (1975, p. 879, pl. 249, figs. 1-24) from the Bone Spring Formation of the Sierra Diablo, West Texas in size and external ornament of pedicle valve, but the accurate comparison is difficult for the fragmentary specimen.

Suborder Strophalosiidina Waagen, 1883
Superfamily Lyttonioidea Waagen, 1883
Family Lyttoniidae Waagen, 1883
Subfamily Lyttoniinae Waagen, 1883
Genus *Eolyttonia* Frederiks, 1924

Eolyttonia sp.
Pl. 1, figs. 7a, 7b.

Material.–One internal mould of a pedicle valve, NU-B78.

Remarks.–This specimen is safely assigned to the genus *Eolyttonia* by having grooved (angustilobate) lateral septa in the pedicle valve. The Hiyomo species is a flat, medium-sized *Eolyttonia* (length more than 29 mm, width more than 32 mm), and is characterized by regularly and symmetrically arranged lateral lobes on both sides of median lobe, numbering 5 lobes on each side.

The type species, *Eolyttonia mira* (Frederiks, 1916), described and figured from the Middle Permian of Ussuri, Far East of Russia (Frederiks, 1916, p. 74, pl. 2, figs. 8, 9; pl. 4, fig. 1) is clearly distinguished from the Hiyomo species by its more inflated, smaller pedicle valve.

Eolyttonia nakazawai Shimizu (1961, p. 330, pl. 15, fig. 22) from the Middle Maizuru Group

(*Lepidolina kumaensis* Zone after Shimizu, 1987) of Takauchi, Kyoto Prefecture, southwest Japan differs from the present species in its much smaller dimensions.

Order Rhynchonellida Kühn, 1949
Superfamily Rhynchonellacea Gray, 1848
Family Wellerellidae Likharev *in* Rzhonsnitzkaja, 1956
Subfamily Wellerellinae Likharev *in* Rzhonsnitzkaja, 1956
Genus *Cenorhynchia* Cooper and Grant, 1976

Cenorhynchia? sp.
Pl. 1, figs. 8a-8d.

Material.–One specimen with valves conjoined, NU-B79.

Remarks.–The imperfect specimen, broken off the anterior portion, is assigned tentatively to the genus *Cenorhynchia* on the basis of its small (length about 11 mm, width 11 mm, thickness 7 mm) and rhynchonelliform shell ornamented by few, weak costae (2 on ventral sulcus and 3 on dorsal fold) near the anterior margin, and possessing two short dental plates.

This specimen resembles shells of *Cenorhynchia triangulata* Cooper and Grant (1976a, p. 1994, pl. 546, figs. 26-39) from the Word Formation of the Glass Mountains, West Texas in size, outline and surface ornament, but the accurate comparison is difficult for the poor specimen.

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen. 1883
Superfamily Martinioidea Waagen, 1883
Family Martiniidae Waagen, 1883
Subfamily Martiniinae Waagen, 1883
Genus *Martinia* M'Coy, 1844

Martinia semiplana Waagen, 1883
Pl. 1, figs. 9a-9d.

1883 *Martinia semiplana* Waagen, p. 536, pl. 43, figs. 4a-e.
1897 *Martinia semiplana* Waagen: Diener, p. 52, pl. 8, figs. 7a-d.
1914 *Martinia semiplana* Waagen: Tschernyschew, p. 23, 57, pl. 10, figs. 5, 6.
1936 *Martinia semiplana* Waagen: Grabau, p. 237, pl. 24, figs. 1-4.
1961 *Martinia semiplana* Waagen: Zhang and Ching, p. 406, pl. 2, figs. 16-19.
1978 *Martinia semiplana* Waagen: Tong, p. 262, pl. 90, figs. 12a-e.
1990 *Martinia semiplana* Waagen: Zeng, p. 228, pl. 7, figs. 6, 7; pl. 8, figs. 11a-d.

Material.–Two specimens: (1) one specimen with valves conjoined, NU-B80; (2) one pedicle valve, NU-B81.

Description.–Shell small size for genus, slightly wider than long, rounded subpentagonal in outline, with greatest width at midvalve; length about 15 mm, width about 16 mm in a better preserved specimen (NU-B80). Pedicle valve strongly and evenly convex in lateral profile. Beak lacking and not observed in the present material. Interarea small, concave, with a wide delthyrium. Sulcus narrow and shallow, developed on the whole length of pedicle valve. Brachial valve slightly convex in lateral and anterior profiles, with a low fold. External surface of both valves smooth.

Remarks.–The Hiyomo specimens can be referred to *Martinia semiplana* Waagen, 1883 by their small-sized, rounded subpentagonal-shaped shell, with a shallow ventral sulcus and a low dorsal fold. This species was originally described by Waagen (1883) from the Wargal Formation of the Salt Range, and afterwards reported by several authors (Diener, 1897; Tschernyschew, 1914; Grabau, 1936; Zhang and Ching, 1961; Tong, 1978; Zeng, 1990) from the Upper Carboniferous to Upper Permian of the Pamirs, Kumaon Himalayas, South China (Sichuan, Guizhou, Anhui), and Inner Mongolia.

Shells identified as *M. semiplana*, from the Middle Permian Kanokura Formation of the southern Kitakami Mountains, northeast Japan (Hayasaka and Minato, 1956, p. 146, pl. 23, fig. 2) are distinguished from the present species by their larger size and more rounded outline.

Martinia fucina Cooper and Grant (1976a, p. 2267, pl. 631, figs. 27-42) from the Bone Spring Formation of the Sierra Diablo, West Texas is also a small *Martinia*, but differs from *M. semiplana* in its transversely subelliptical shell and the presence of a lower ventral sulcus.

Martinia sp.
Pl. 1, fig. 10.

Material.–One brachial valve, NU-B82.

Remarks.– The specimen of Hiyomo is a fragment of a brachial valve, but safely assigned to the genus *Martinia* on the basis of its rounded outline and surface ornament of only a few weak concentric rugae. The Hiyomo species is an average-sized *Martinia*, measuring about 20 mm long and about 26 mm wide in the brachial valve, and is characterized by its transversely elliptical-shaped brachial valve, with a high, prominent fold on the anterior half.

The present species somewhat resembles *Martinia remota* Chao (1929,p .78, pl. 10, figs. 8a-e) from the Upper Carboniferous of Guizhou, South China, and also *Martinia* sp. Yanagida (1975, p. 16, pl. 2, fig. 2) from the Upper Carboniferous of Wang Saphung, Northern Thailand in having a prominent dorsal fold. But it is difficult for the Hiyomo specimen to compare with both the South China and Northern Thailand species from its poor preservation.

Superfamily Spiriferoidea King, 1846
Family Trigonotretidae Schuchert, 1893
Subfamily Neospiriferinae Waterhouse, 1968

Genus *Cartorhium* Cooper and Grant, 1976

Cartorhium coristum Cooper and Grant, 1976
Pl. 2, figs. 1a-1e.

1976 *Cartorhium coristum* Cooper and Grant, p. 2193, pl. 613, figs. 36-39; pl. 614, figs.1-25.

Material.–Two specimens: (1) one specimen with valves conjoined, NU-B83; (2) one pedicle valve, NU-B84.

Description.–Shell medium size for genus, transversely subelliptical in outline, with greatest width near midvalve; length about 26 mm, width 35 mm, thickness 18 mm in a better preserved specimen (NU-B83).

Pedicle valve strongly convex in lateral profile; beak not preserved; interarea high, triangular; cardinal extremities rounded; sulcus wide and deep, V-shaped in anterior profile; lateral slopes gently inclined. Brachial valve less convex than pedicle valve in lateral profile; fold high and sharply pointed anteriorly. External surface of both valves ornamented by numerous bundled costae. Costae strong, rounded, distinctly fasciculate, numbering 12-14 in 10 mm near anterior margin, and having 3-6 per fascicle. Concentric ornament not preserved.

Remarks.–These specimens are referred to *Cartorhium coristum* Cooper and Grant (1976a, p. 2193, pl. 613, figs. 36-39; pl. 614, figs. 1-25) from the Cathedral Mountain Formation (Wedin Member) of the Glass Mountains, West Texas, on account of their size, shape and external ornament, especially the high, triangular ventral interarea, deep and V-shaped sulcus, and high, angular fold.

The type species, *Cartorhium retusum* Cooper and Grant (1976a, p. 2200, pl. 617, figs. 21-26; pl. 618, figs. 1-29), from the Cherry Canyon and Word formations of West Texas, differs from the present species in its large size and in having a low fold on the brachial valve.

Genus *Lepidospirifer* Cooper and Grant, 1969

Lepidospirifer miyakei n. sp.
Pl. 2, figs. 2-6.

Material.–Seven specimens: (1) one pedicle valve, NU-B85 (holotype, pl. 2, fig. 5); (2) one brachial valve, NU-B86; (3) four brachial valves, NU-B87-90; (4) one fragment of a conjoined valve, NU-B91.

Diagnosis.–Large, flattened *Lepidospirifer,* with very weakly fasciculate costae on both valves.

Description.–Shell large size for genus, transversely subpentagonal in outline, with rounded cardinal extremities, and greatest width occurring slightly anterior to hinge line; length about 56 mm, width about 78 mm in the largest pedicle valve (NU-B85, holotype), length about 34 mm, width 51 mm in the best preserved brachial valve (NU-B86).

Pedicle valve gently convex in lateral profile; beak elongated, strongly incurved, but the curva-

ture may be owing to deformation; delthyrium open, widely triangular in shape; interarea slightly concave; sulcus wide and shallow, originating at beak, widening and deepening anteriorly; lateral slopes slightly convex, gently inclined to anterolateral margins. Brachial valve gently convex in lateral profile, but nearly flat in anterior profile except for median fold; fold moderately high, beginning from beak and rapidly widening anteriorly.

External surface of both valves ornamented by numerous costae and few irregularly developed concentric rugae. Costae strong, with rounded crests, and bearing numerous concentric scales, giving tiled-roof appearance. Fasciculation of costae distinct on posterior portion, but obscure anteriorly. Costae increasing in number by bifurcation; 8-10 in 10 mm near anterior margin.

Remarks.–*Lepidospirifer miyakei* is characterized by its large, weakly biconvex shell, ornamented by numerous, obscurely fasciculate costae. The new species from Hiyomo most resembles shells of *Lepidospirifer costellus* (King, 1930), redescribed and refigured by Cooper and Grant (1976a, p. 2205, pl. 621, figs. 15-21; pl. 624, figs. 11-16) from the Cathedral Mountain Formation of the Glass Mountains, West Texas in size and outline, but differs in having less distinctly fasciculate costae on both valves.

Superfamily Reticularioidea Waagen, 1883
Family Elythidae Frederiks, 1924
Subfamily Anomaloriinae Cooper and Grant, 1976
Genus *Anomaloria* Cooper and Grant, 1969

Anomaloria hiyomoensis n. sp.
Pl. 2, figs. 7-12.

Material.–Eighteen specimens: (1) six conjoined valves, NU-B92 (holotype, pl. 2, figs. 7a-7d), 93-97; (2) five pedicle valves, NU-B98-102; (3) seven brachial valves, NU-B103-109.

Diagnosis.–Medium, elongately triangular *Anomaloria*, with commissure of weakly uniplicate, and having high interarea and long, acute beak on pedicle valve.

Description.–Shell medium size for genus, subtriangular in outline, weakly uniplicate, longer than wide, with greatest width slightly anterior to midvalve; length 25 mm, width about 24 mm, thickness 14 mm in the holotype (NU-B92); length about 30 mm, width about 26 mm, thickness 17 mm in the largest specimen (NU-B95).

Pedicle valve gently convex in lateral profile, but strongly convex in anterior profile; beak fairly long, thin, acute and slightly incurved; interarea extremely high, triangular in shape; delthyrium wholly covered by convex pseudodeltidium; sulcus shallow, originating at one-third of shell length from umbo, and gradually widening anteriorly; lateral slopes steeply inclined to margins. Brachial valve semicircular to subelliptical in outline, slightly convex in both of lateral and anterior profiles; beak short and blunt; fold absent or very low on anterior half of valve.

External surface of both valves ornamented by concentric lamellae and numerous spine bases; concentric lamellae numbering 7 in 5 mm near anterior margin; spine bases usually not seen, but in

one pedicle valve specimen (NU-B99) a row of numerous, closely arranged, fine, elongate pustules is observed on each lamella.

Remarks.–Anomaloria hiyomoensis n. sp. is characterized by its subtriangular-shaped shell, with a very high interarea, a shallow ventral sulcus and a low dorsal fold. There is no species have such a high interarea besides the present species.

The type species, *Anomaloria anomala* Cooper and Grant (1969, p. 16, pl. 3, figs. 8-13) from the Bell Canyon Formation of the Guadalupe Mountains, West Texas, differs from *A. hiyomoensis* in its roundly elliptical-shaped, rectimarginate shell, with a lower ventral interarea.

Acknowledgements

We thank Mr. Y. Miyake of Miya-mura, Ono-gun, Gifu Prefecture for providing brachiopod specimens he collected; Dr. S. Otoh of the Department of Earth Sciences, Toyama University for information on geology of the fossil locality; Dr. Y. Hasegawa of the Department of Geology, Niigata University for identification of fusulinids collected from the same locality.

References

Adachi, M. and Kojima, S., 1983, Geology of the Mt. Hikagedaira area, east of Takayama, Gifu Prefecture, central Japan. *Jour. Earth Sci., Nagoya Univ.*, **31**, 37-67.

Chao, Y.T., 1929, Carboniferous and Permian spiriferids of China. *Palaeont. Sinica, Ser. B*, **11**, 1-133.

Cooper, G.A. and Grant, R.E., 1969, New Permian brachiopods from West Texas. *Smithson. Contr. Paleobiol.*, no. 1, 1-20.

Cooper, G.A. and Grant, R.E., 1975, Permian brachiopods of West Texas, 3. *Smithson. Contr. Paleobiol.*, no. 19, 795-1298 (text), 1299-1921 (plates).

Cooper, G.A. and Grant, R.E., 1976a, Permian brachiopods of West Texas, 4. *Smithson. Contr. Paleobiol.*, no. 21, 1923-2286 (text), 2287-2607 (plates).

Cooper, G.A. and Grant, R.E., 1976b, Permian brachiopods of West Texas, 5. *Smithson. Contr. Paleobiol.*, no. 24, 2609-3159.

Diener, C., 1897, Himalayan fossils, Vol. 1, Part 3. The Permocarboniferous fauna of Chitichun, No. 1.*Palaeont. Indica, Ser. 15*, **1**, 1-105.

Frederiks, G., 1916, The palaeontological notes, 2. On some Upper Palaeozoic Brachiopoda of Eurasia. *Mém. Com. Géol., N. S.*, **156,** 1-87. (In Russian).

Grabau, A.W., 1936, Early Permian fossils of China, Pt. 2. Fauna of the Maping Limestone of Kwangsi and Kweichow. *Palaeont. Sinica, Ser. B*, **8,** 1-441.

Hattori, I., 1982, The Mesozoic evolution of the Mino Terrane, central Japan: a geologic and paleomagnetic synthesis. *Tectonophysics*, **85**, 313-340.

Hattori, I. and Hirooka, K., 1977, Paleomagnetic study of the greenstone in the Mugi-Kamiaso area, Gifu Prefecture, central Japan. *Jour. Japan. Assoc. Min. Petr. Econ. Geol.*, **72**, 340-353.

Hattori, I. and Hirooka, K., 1979, Paleomagnetic results from Permian greenstones in central Japan and their geologic significance. *Tectonophysics*, **57**, 211-235.

Hayasaka, I., 1925, On *Lyttonia* and other brachiopods from Kinshozan. *Jour. Geol. Soc. Japan*, **32**, 142-146. (In Japanese).

Hayasaka, I., 1932, On three brachiopod species of the subfamily Orthotetinae in the Fusulina Limestone of Kinshozan, Akasaka-mati, Prov. Mino, Japan. *Mem. Fac. Sci. Agric., Taihoku Imp. Univ.*, **4**, 1-7.

Hayasaka, I. and Minato, M., 1956, Some brachiopods from the Lower Kanokura Series of the Kitakami Mountains, Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 21, 141-147.

Imazato, A. and Otoh, S., 1993, Jurassic radiolarians from the Nyukawa area, northernmost part of the Mino Belt. *News, Osaka Micropaleontol., Spec. vol.*, no. 9, 131-141. (In Japanese).

King, R.E., 1930, The geology of the Glass Mountains, Texas, Pt. 2. Faunal summary and correlation of the Permian formations with description of Brachiopoda. *Univ. Texas Bull.*, no. 3042, 1-245.

Mills, P.C. and Langenheim, R.L.Jr., 1987, Wolfcampian brachiopods from the Bird Spring Group, Wamp Spring area, Las Vegas Range, Clark County, Nevada. *Jour. Paleontology*, **61**, 32-55.

Muir-Wood, H.M. and Cooper, G.A., 1960, Morphology, classification and life habits of the Productoidea (Brachiopoda). *Geol. Soc. Amer., Mem.*, **81**, 1-447.

Ozawa, T., 1987, Permian fusulinacean biogeographic provinces in Asia and their tectonic implications. *In* Taira, A. and Tashiro, M., eds., *Historical biogeography and plate tectonic evolution of Japan and eastern Asia.* Terra Sci. Pub., Tokyo, 45-63.

Ozawa, Y., 1927, Stratigraphical studies of the Fusulina Limestone of Akasaka, Province of Mino. *Jour. Fac. Sci., Imp. Univ. Tokyo, Sec. 2*, **2**, 121-164.

Sano, H. and Kanmera, K., 1996, Microbial controls on Panthalassan Carboniferous-Permian oceanic buildups, Japan. *Facies*, **34**, 59-61.

Sato, D., 1919, On *Lyttonia* recently discovered at Akasaka, Prov. Mino. *Jour. Geol. Soc. Tokyo*, **26**, 276-277. (In Japanese).

Shimizu, D., 1961, Brachiopod fossils from the Permian Maizura Group. *Mem. Coll. Sci., Univ. Kyoto, Ser. B*, **27**, 309-351.

Shimizu, D., 1987, Maizuru Zone, (1) 1-4. *In* Nakazawa, K., Ichikawa, K. and Ichihara, M., eds., *Geology of Japan, 6. Kinki area.* Kyoritsu Shuppan, Tokyo, 8-12. (In Japanese).

Tong, Z., 1978, Carboniferous and Permian Brachiopoda. *In* Geological Institute of Southwest China, ed., *Palaeontological Atlas of Southwest China; Sichuan, Part 2. Carboniferous to Mesozoic.* Geol. Pub. House, Beijing, 210-267. (In Chinese).

Tschernyschew, Th.N., 1914, Die Fauna der oberpalaeozoischen Ablagerungen des Darvas. *Mém. Com. Géol., N. S.*, **104**, 1-66. (In Russian).

Waagen, W., 1883, Salt Range fossils, 1. Productus-Limestone fossils. *Palaeont. Indica, Ser. 13*, **1**, 391-546.

Waagen, W., 1884, Salt Range fossils, 1. Productus-Limestone fossils. *Palaeont. Indica, Ser. 13*, 1, 547-728.

Waterhouse, J.B., 1976, World correlations for Permian marine faunas. *Univ. Qd. Pap., Dept. Geol.*, **7**, 1-232.

Yanagida, J., 1975, Upper Carboniferous brachiopods from Wang Saphung, North Thailand. *In* Kobayashi, T. and Toriyama, R., eds., *Geology and palaeontology of Southeast Asia*, **16**, Univ. Tokyo Press, Tokyo, 1-31.

Zeng, Y., 1990, Description of brachiopods. *In* He, X., Zhang, Y., Zhu, M., Zhang, G., Zhuang, S., Zeng, Y. and Song, P., *Research on the Late Paleozoic coal-bearing stratigraphy and biota in Jungar, Nei Mongol (Inner Mongolia).* China Univ. Min. Tech. Press, Xuzhou, 205-237, 380-387. (In Chinese).

Zhang, Y. and Ching, Y., 1961, An Upper Permian Brachiopoda fauna from Jingxian, Anhui Province. *Acta. Palaeont. Sinica*, **9**, 401-417. (In Chinese).

Explanation of Plates

(Natural size unless otherwise indicated)

Plate 1

Figs. 1a, 1b. *Enteletes* sp.
1a, 1b. Incomplete pedicle valve in ventral view, NU-B71, Fig. 1b is ×2.

Figs. 2a, 2b. *Chonetinella* cf. *costellata* Cooper and Grant
2a, 2b. Pedicle valve in ventral view, NU-B72, Fig. 2b is ×4.

Figs. 3a, 3b. *Ametoria* cf. *residua* Cooper and Grant
3a, 3b. Pedicle valve in ventral view, NU-B73, Fig. 3b is ×2.

Figs. 4a-4c. *Calliprotonia* sp.
4a, 4b. Incomplete brachial valve in dorsal view, 4c. Portion of surface enlarged, NU-B74, Fig. 4b is ×2, Fig. 4c is ×10.

Figs. 5a, 5b. *Compressoproductus* sp.
5a, 5b. Incomplete pedicle valve in ventral view, NU-B76, Fig. 5b is ×2.

Figs. 6a, 6b. *Glyptosteges*? sp.
6a, 6b. Pedicle valve in ventral view, NU-B77, Fig. 6b is ×5.

Figs. 7a, 7b. *Eolyttonia* sp.
7a. Internal mould of pedicle valve in ventral view, 7b. Rubber cast of pedicle valve in ventral view, NU-B78.

Figs. 8a-8d. *Cenorhynchia*? sp.
8a, 8b, 8c, 8d. Shell in ventral, dorsal and lateral views, NU-B79, Figs. 8b-8d are ×2.

Figs. 9a-9d. *Martinia semiplana* Waagen
9a, 9b, 9c, 9d. Incomplete shell in ventral, dorsal and lateral views, NU-B80, Figs. 9b-9d are ×2.

Fig. 10. *Martinia* sp.
Incomplete brachial valve in dorsal view, NU-B82.

Plate 1

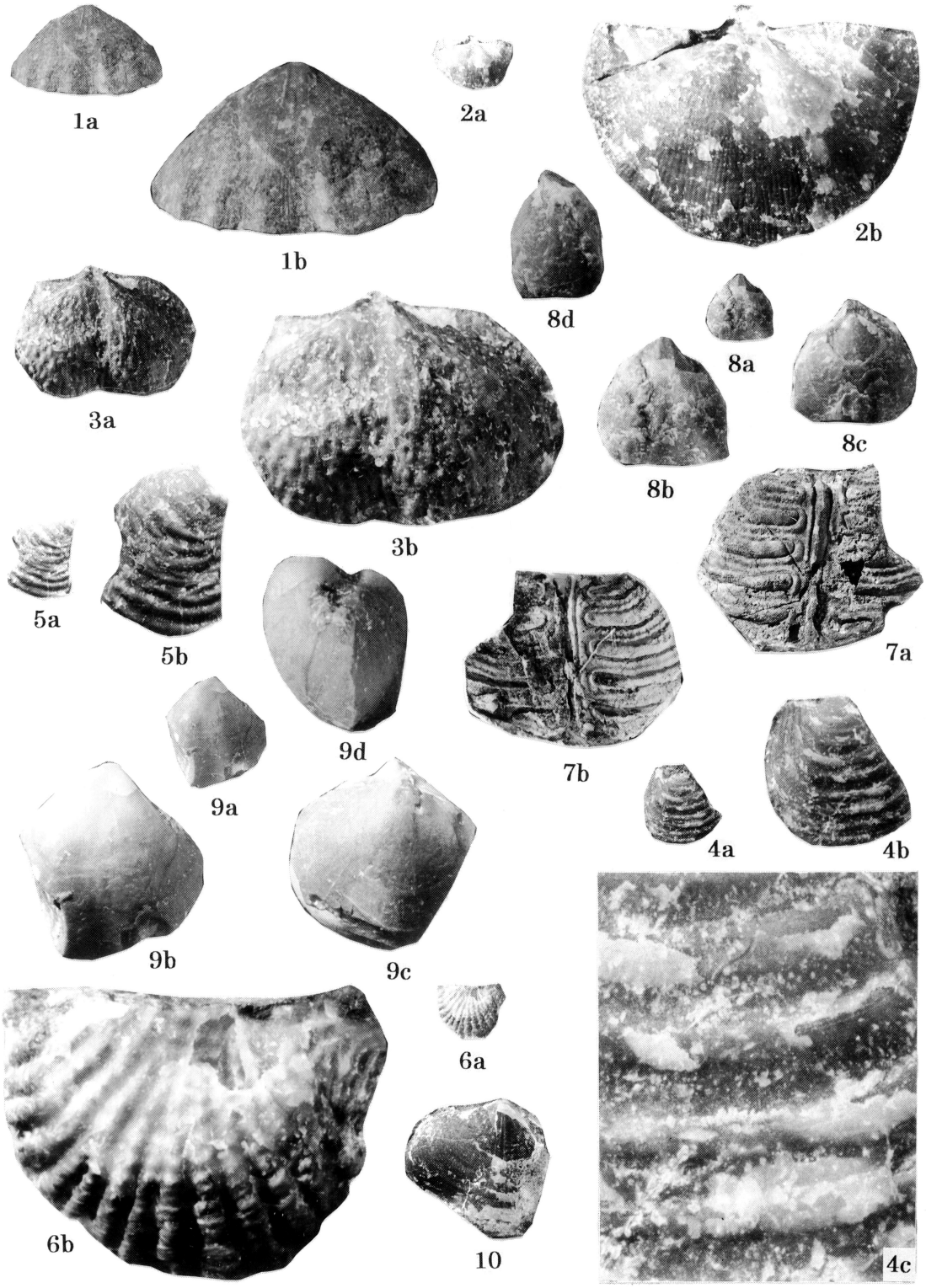

Plate 2

Figs. 1a-1e. *Cartorhium coristum* Cooper and Grant

1a, 1b, 1c, 1d, 1e. Shell in ventral, dorsal, anterior, posterior and lateral views, NU-B83.

Figs. 2-6. *Lepidospirifer miyakei* Tazawa and Shen, n. sp.

2. Brachial valve in dorsal view, NU-B86, 3. Rubber cast of brachial valve in dorsal view, NU-B87, 4. Incomplete brachial valve in dorsal view, NU-B89, 5. Pedicle valve in ventral view, NU-B85 (holotype), 6. Portion of external mould of brachial valve enlarged, NU-B88, Fig. 6 is ×3.

Figs. 7-12. *Anomaloria hiyomoensis* Tazawa and Shen, n. sp.

7a, 7b, 7c, 7d. Shell in ventral, dorsal, posterior and lateral views, NU-B92 (holotype), 8. Pedicle valve in ventral view, NU-B98, 9. Incomplete shell in ventral view, NU-B93, 10. Brachial valve in dorsal view, NU-B104, 11. Brachial valve in dorsal view, NU-B103, 12. Incomplete pedicle valve in ventral view, NU-B99.

Plate 2