Lamnimargus (Productida, Brachiopoda) from the Upper Permian of Ofunato in the South Kitakami Belt, NE Japan, and its palaeobiogeographical significance

Jun-ichi TAZAWA*

Abstract

A brachiopod species *Lamnimargus peregrinus* (Fredericks, 1924) is described from the Upper Permian (Changhsingian) Toyoma Formation of the Ofunato area, South Kitakami Belt, northeast Japan. The occurrence of *L. peregrinus* from the Upper Permian of the South Kitakami Belt is a reliable evidence for the palaeobiogeographical link between the South Kitakami region and Northeast Asia including North China, Northeast China and eastern Russia in the Middle to Late Permian time.

Key words: bipolar-type, brachiopod, *Lamnimargus*, Ofunato, South Kitakami Belt, Upper Permian.

Introduction

Lamnimargus peregrinus (Fredericks, 1924) is a productid brachiopod, originally described by Fredericks (1924) as a species of the genus *Paramarginifera* Fredericks, 1916 from the Middle Permian Chandalaz Formation of the Vladivostok area, South Primorye, eastern Russia. This species have hitherto been found from the Middle Permian (Wordian) to Upper Permian (Lopingian) of North China (Inner Mongolia), Northeast China (Heilongjiang) and eastern Russia (South Primorye).

The specimens of *Lamnimargus peregrinus*, described in this paper, were collected by M. Ehiro and Y. Miyake from two localities, Loc. A and Loc. B in Maeda, Ikawa-cho, Ofunato City, Iwate Prefecture in the South Kitakami Belt, northeast Japan (Fig. 1). The fossil bearing beds are dark grey to black shale or sandy shale of the upper part of the Toyoma Formation. The age of the shale beds is considered to be a Changhsingian, based on some ammonoids

* Department of Geology, Faculty of Science, Niigata University, Niigata, 950-2181, Japan
(Manuscript received 4 January, 2008; accepted 30 January, 2008)

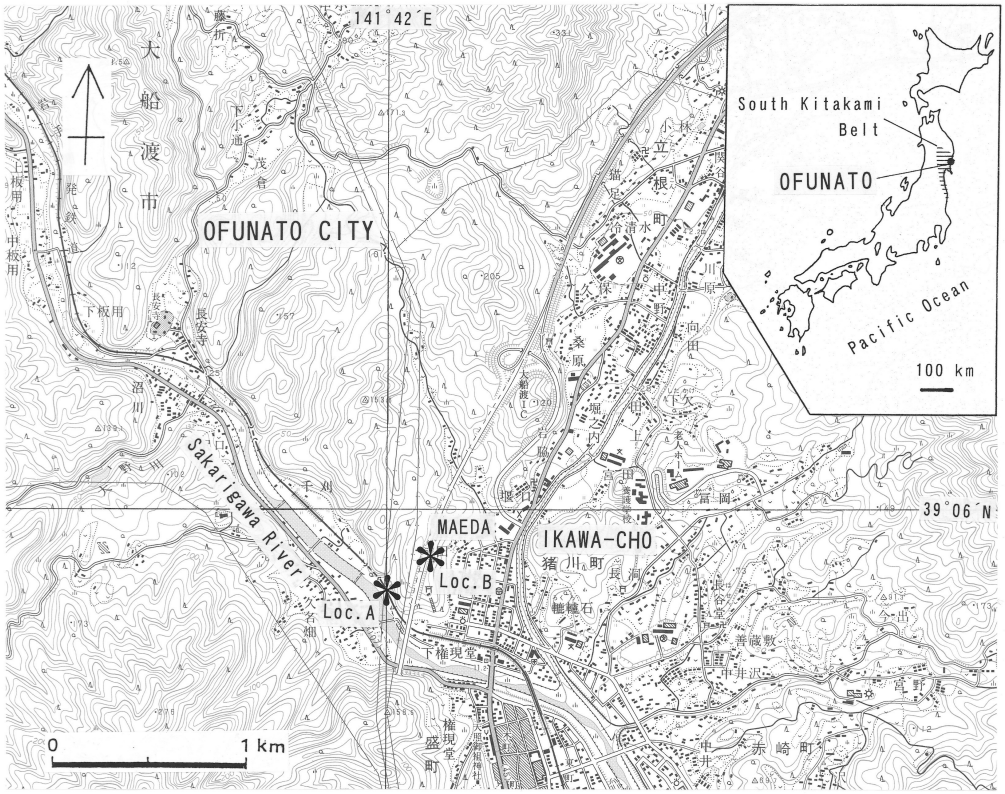

Fig. 1. Index map of the fossil localities (Loc. A, Loc. B) in the Ofunato area, South Kitakami Belt, northeast Japan (using the topographical map of "Sakari" scale 1:25,000 published by the Geographical Survey Institute of Japan).

Paratirolites compressus Ehiro and *Paratirolites* sp. (Ehiro, 1996), and bivalves *Girtypecten* cf. *beipeiensis* Liu and *Etheripecten*? sp. (Nakazawa, 1998).

In Japan *Lamnimarugus* species was first described by Tazawa (1975) as *Paramarginifera japonica* Tazawa, 1975, from the Upper Permian (Changhsingian) Toyoma Formation of Nabekoshiyama in the Kesennuma area, South Kitakami Belt. Recently this species was redescribed as *Lamnimargus japonicus* (Tazawa, 1975) on the specimens from both of the Toyoma Formation of Nabekoshiyama in the South Kitakami Belt and the Upper Permian (Changhsingian) Maizuru Group of Kawahigashi in the Maizuru Belt, southwest Japan (Tazawa, 2006a, b). Therefore, two species of *Lamnimargus* have been recognized from the Upper Permian of Japan: *Lamnimargus japonicus* (Tazawa) from the South Kitakami and Maizuru Belts and *Lamnimargus peregricus* (Fredericks) from the South Kitakami Belt.

In this paper, the specimens of *Lamnimargus peregrinus*, collected from the Upper Permian (Changhsingian) of Maeda, Ofunato City are described, and the global stratigraphical and geographical distributions of the genus *Lamnimargus* are summarized.

Table 1. Stratigraphical and geographical distributions of *Lamnimargus*.

Species \ Stage & Region	Stage				Region										
	Wordian	Capitanian	Wuchiapingian	Changhsingian	Karakorum	Kashmir	Punjab Himalayas	Central Himalayas	Tibet	Gansu	Inner Mongolia	Heilongjiang	South Primorye	South Kitakami	Maizuru
Lamnimargus himalayensis (Diener)		—	—	—	+	+	+	+	+	+					
Lamnimargus peregrinus (Fredericks)	—	—	—	—							+	+	+	+	
Lamnimargus gobiensis (Chao)	—	—									+				
Lamnimargus japonicus (Tazawa)				—										+	+
?*Lamnimargus* sp. Shen, Archbold, Shi & Chen	—	—							+						

Furthermore, palaeobiogeographical significance of the occurrence of *Lamnimargus* from the South Kitakami is discussed. All the specimens described in this paper are housed in the Department of Geology, Faculty of Science, Niigata University.

Stratigraphical and geographical distributions of *Lamnimargus*

The genus *Lamnimargus* was proposed by Waterhouse (1975, p. 10) with *Marginifera himalayensis* Diener, 1899 as type species. The following five species of this genus have been described from the Middle Permian (Wordian) to Upper Permian (Changhsingian) of northern India, Nepal, North China, Northeast China, eastern Russia and Japan (Table 1, Fig. 2).

Lamnimargus himalayensis (Diener, 1899): Middle-Upper Permian (Capitanian-Wuchiapingian) of Mt. Qomolangma, Xizang (Tibet) (Zhang and Ching, 1976), Lachi Ridge, Tibet (Muir-Wood in Muir-Wood and Oakley, 1941); Beishan, Gansu Province, North China (Ustritsky, 1963); Upper Permian (Wuchiapingian) of Upper Shyok Valley, Ladakh, southern Karakorum Range (Waterhouse and Gupta, 1983) and Lissar Valley, Byans and Dolpo, Central (Nepal) Himalayas (Diener, 1903; Waterhouse, 1978); Upper Permian (Lopingian) of Kashmir (Diener, 1915; Shimizu, 1981) and Spiti, Punjab Himalayas (Diener, 1899, 1903; Gupta and Waterhouse, 1979).

Lamnimargus peregrinus (Fredericks, 1924): Middle Permian (Wordian-Capitanian) of Zhesi (Jisu) and Xiujimqinqi, Inner Mongolia, North China (Lee and Gu, 1976; Duan and Li, 1985; Wang and Zhang, 2003), Acheng, Heilongjiang Province, Northeast China (Lee et al., 1980) and Vladivostok and Artemovka, South Primorye, eastern Russia (Fredericks, 1924, 1925; Licharew and Kotlyar, 1978); Upper Permian (Wuchiapingian) of Trudny Peninsula,

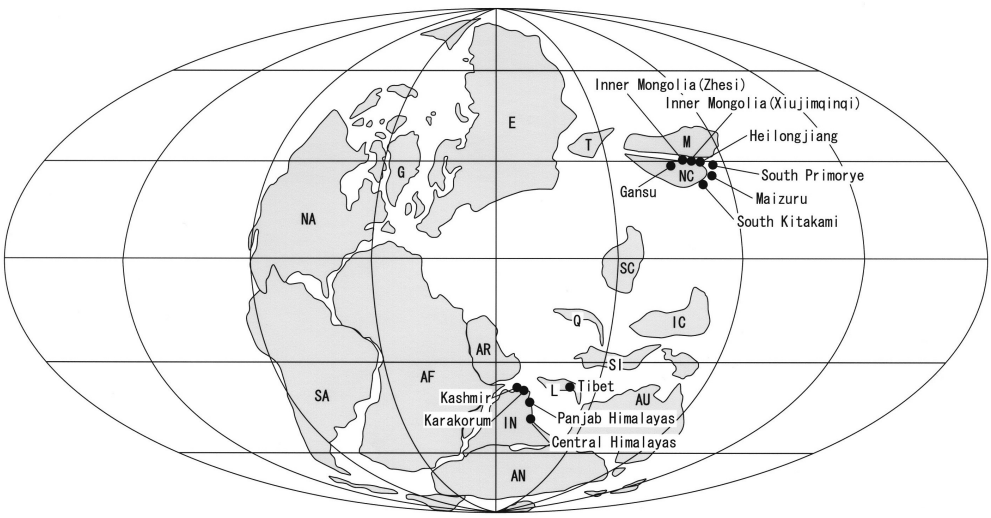

Fig. 2. Geographical distribution of *Lamnimargus* in the Middle to Late Permian (plotted on the base map by Ziegler et al., 1997). AF: Africa, AN: Antarctica, AR: Arabia, AU: Australia, E: Eurasia, G: Greenland, IC: Indochina, IN: India, L: Lhasa, M: Mongolia, NA: North America, NC: North China, Q: Qiangtang, SA: South America, SC: South China, SI: Sibumasu, T: Tarim.

South Primorye, eastern Russia (Kotlyar in Kotlyar and Zakharov, 1989); Upper Permian (Changhsingian) of Ofunato, South Kitakami Belt, northeast Japan (this study).

Lamnimargus gobiensis (Chao, 1927): Middle Permian (Wordian-Capitanian) of Zhesi (Jisu), Inner Mongolia, North China (Chao, 1927).

Lamnimargus japonicus (Tazawa, 1975): Upper Permian (Changhsingian) of Nabekoshiyama, South Kitakami Belt, northeast Japan (Tazawa, 1975, 1976, 2006b; Minato et al., 1979) and Kawahigashi, Maizuru Belt, southwest Japan (Shimizu, 1961; Tazawa, 2006a, b).

?*Lamnimarugus* sp. Shen, Archbold, Shi and Chen, 2000: Middle-Upper Permian (Capitanian-Wuchiapingian) of Selong, southern Xizang (Tibet) (Shen, Archbold, Shi and Chen, 2000).

Discussion

As shown in Table 1 and Fig. 2, the genus *Lamnimargus* displays a typical bipolar distribution in the Middle to Late Permian time. The occurrence of *Lamnimargus* from the South Kitakami Belt, northeast Japan indicates that the South Kitakami region was located at the mid-latitude area of the Northern Hemisphere, and in addition to this, this rgion was probably close geographically to South Primorye, eastern Russia, Northeast China and Inner Mongolia in the Late Permian. This conclusion coincides with and supports the Permian reconstruction of

eastern Asia by Tazawa (2000, 2007), in which the South Kitakami region is being a continental margin of North China (Sino-Korea). Shen, Archbold and Shi (2000, fig. 3) also illustrated the South Kitakami region on the eastern margin of North China in their palaeobiogeographical world map in the Changhsingian.

On the other hand, Nakazawa (1991) mentioned that the Middle and Upper Permian bivalve faunas of the South Kitakami region is allied to that of South China (Yangze) and subsequently he emphasized that one of the bivalves from the Upper Permian of Ofunato, *Girtypecten* cf. *beipeiensis*, is close to the Changhsingian species from South China (Nakazawa, 1998). Ehiro (1997) also considered that the South Kitakami region was a microcontinent, located at equatorial region of Panthalassa and east of South China in the Late Permian, based on the palaeobiogeographical data of ammonoids. The Permian geographical reconstruction of East Asia including the South Kitakami region is still controversial. More convincing data will be need for conclusion of this problem.

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Productellidae Schuchert, 1929
Subfamily Marginiferinae Stehli, 1954
Tribe Paucispiniferini Muir-Wood and Cooper, 1960

Genus *Lamnimargus* Waterhouse, 1975

Type species.—*Marginifera himalayensis* Diener, 1899, from the Kuling Shales of the Spiti area, Punjab Himalayas.

Diagnosis (after Waterhouse, 1975, p. 10).—Shell transverse with wide ears, semigeniculate trail, reticulate ornament over disc of both valves, spines restricted to ventral valve, in hinge row, ear cluster, six halteroid spines, and rare over disc. Ventral interior has somewhat striated adductors, diductors, marginal ridge, with anterior flange or curtain in some individuals. Dorsal interior with cardinal process, septum, divided adductors, marginal ridges, and one or two flanges in some individuals, two-three rows of moderately prominent and numerous pustules over anterior disc.

Remarks.— The genus *Lamnimargus* Waterhouse, 1975 somewhat resembles the genera *Retimarginifera, Paramarginifera* and *Jinomarginifera*.

Retimarginifera Waterhouse, 1970 is similar to *Lamnimargus* in shape and external ornament of the shell, but differs in its smaller size and lacking the second or third trails on both valves,

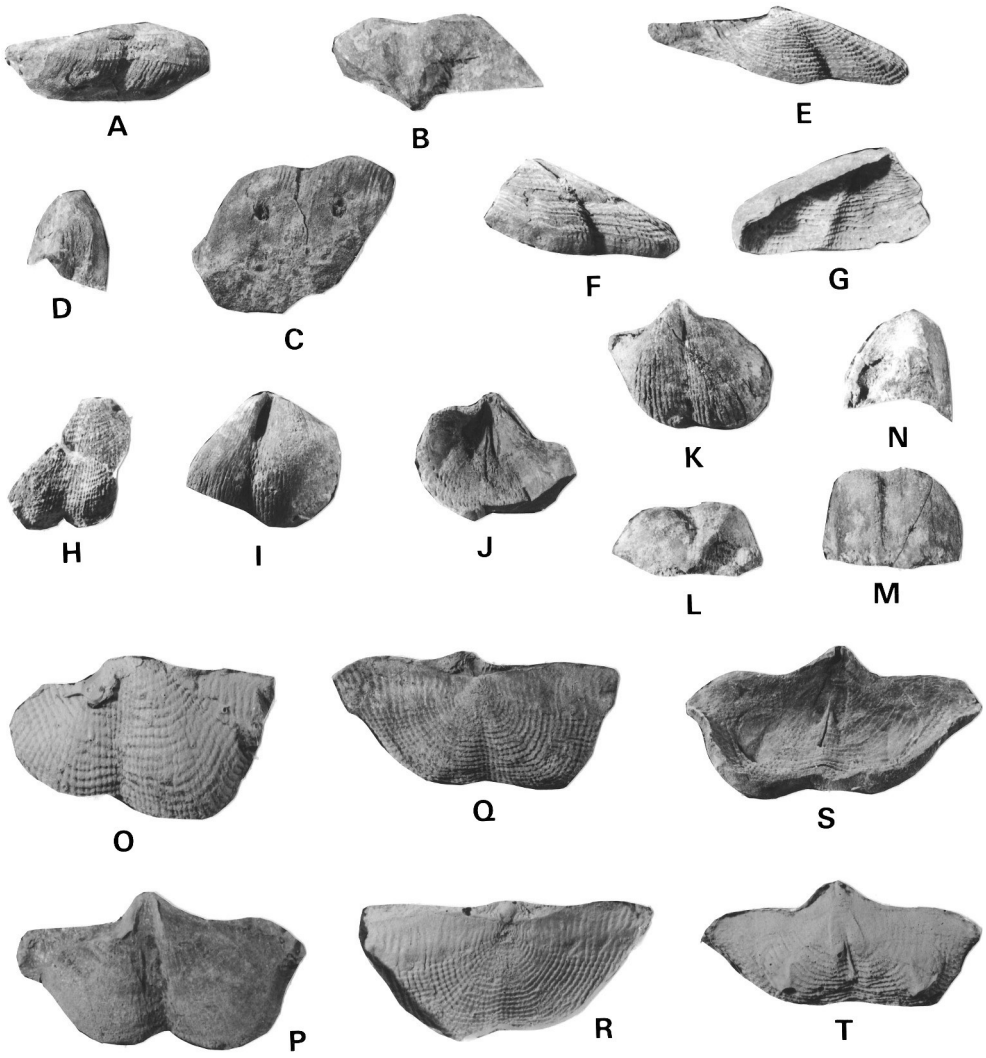

Fig. 3. *Lamnimargus peregrinus* (Fredericks) from the Upper Permian Toyoma Formation of Maeda, Ofunato City, Iwate Prefecture. A-D: ventral (A), posterior (B), anterior (C) and lateral (D) views of internal mould of ventral valve, NU-B1068, E-G: external mould of dorsal valve (E), and ventral (F) and dorsal (G) views of internal mould of conjoined valve, NU-B1066, H-J: external latex cast of ventral valve (H), and ventral (I) and dorsal (J) views of internal mould of conjoined valve, NU-B1065, K-N: ventral (K), posterior (L), anterior (M) and lateral (N) views of internal mould of ventral valve, NU-B1069, O-T: external latex cast of ventral valve (O), internal mould of ventral valve (P), internal mould of dorsal valve (Q), external latex cast of dorsal valve (R), internal mould of dorsal valve (S) and external latex cast of dorsal valve (T), NU-B1063. (All×1).

which occasionally observed for the type species of *Lamnimargus*.

Paramarginifera Fredericks, 1916 differs from *Lamnimargus* in its larger size, weaker reticulate ornament on the ventral valve, and lacking the second or third trails on both valves.

Jinomarginifera Shen, Shi and Archbold, 2003 is similar to *Lamnimargus* in size, shape and reticulate ornament of the shell, but differs in its lacking halteroid spines on the ventral valve, and absent of the second or third trails on both valves.

Lamnimargus peregrinus (Fredericks, 1924)
Figs. 3A-3T

Paramarginifera peregrina Fredericks, 1924, p. 24, pl. 1, figs. 7, 8; Fredericks, 1925, p. 12, pl. 1, figs. 41-44.

Dictyoproductus zesiensis Lee and Gu, 1976, p. 256, pl. 167, figs. 5, 6: pl. 170, figs. 1a, 1b.

Probolionia caucasica peregrina (Fredericks): Licharew and Kotlyar, 1978, pl. 12, figs. 13, 14.

Paramarginifera? *peregrina* Fredericks: Duan and Li, 1985, p. 112, pl. 42, figs. 1-7; Lee et al., 1980, p. 356, pl. 166, figs. 18, 28.

Lamnimargus himalayensis (Diener): Kotlyar in Kotlyar and Zakharov, 1989, pl. 23, figs. 9a, 9b.

Lamnimargus peregrina (Fredericks): Wang and Zhang, 2003, p. 73, pl. 14, figs. 3, 8, 9; pl. 15, fig. 11; pl. 21, figs. 14-16, 22-24.

Material.— Thirteen specimens: (1) external and internal moulds of two conjoined valves, NU-B1063, 1064; (2) internal mould of a conjoined valve with external mould of the ventral valve, NU-B1065; (3) internal mould of a conjoined valve with external mould of the dorsal valve, NU-B1066; (4) external and internal moulds of a ventral valve, NU-B1067; (5) internal moulds of two ventral valves, NU-B1068, 1069; (6) external moulds of six dorsal valves, NU-B1070-1075.

Description.—Shell medium to large size for genus, transversely trapezoidal or subrectangular in outline, widest at hinge; length about 23 mm, width about 42 mm in the largest specimen (NU-B1063). Ventral valve strongly and unevenly convex in lateral profile, gently convex on visceral disc, bluntly geniculated and followed by long trail; umbo small, slightly incurved; ears large, prominent and slightly convex, not clearly demarcated from visceral disc; sulcus narrow and deep, originating near umbo and extending to anterior margin; lateral slopes steep. Dorsal valve almost flattened on visceral disc, strongly geniulated and followed by long trail; fold narrow and low.

External surface of ventral valve ornamented by regular numerous rugae and costae on visceral disc, rugae only on ears, and costae only on trail; costae numbering 8-9 in 5 mm at midvalve. Spine bases are rarely preserved; a row of spine bases on base of ears; a pair of strong spine bases on trail. External ornament of dorsal valve similar to that of opposite valve,

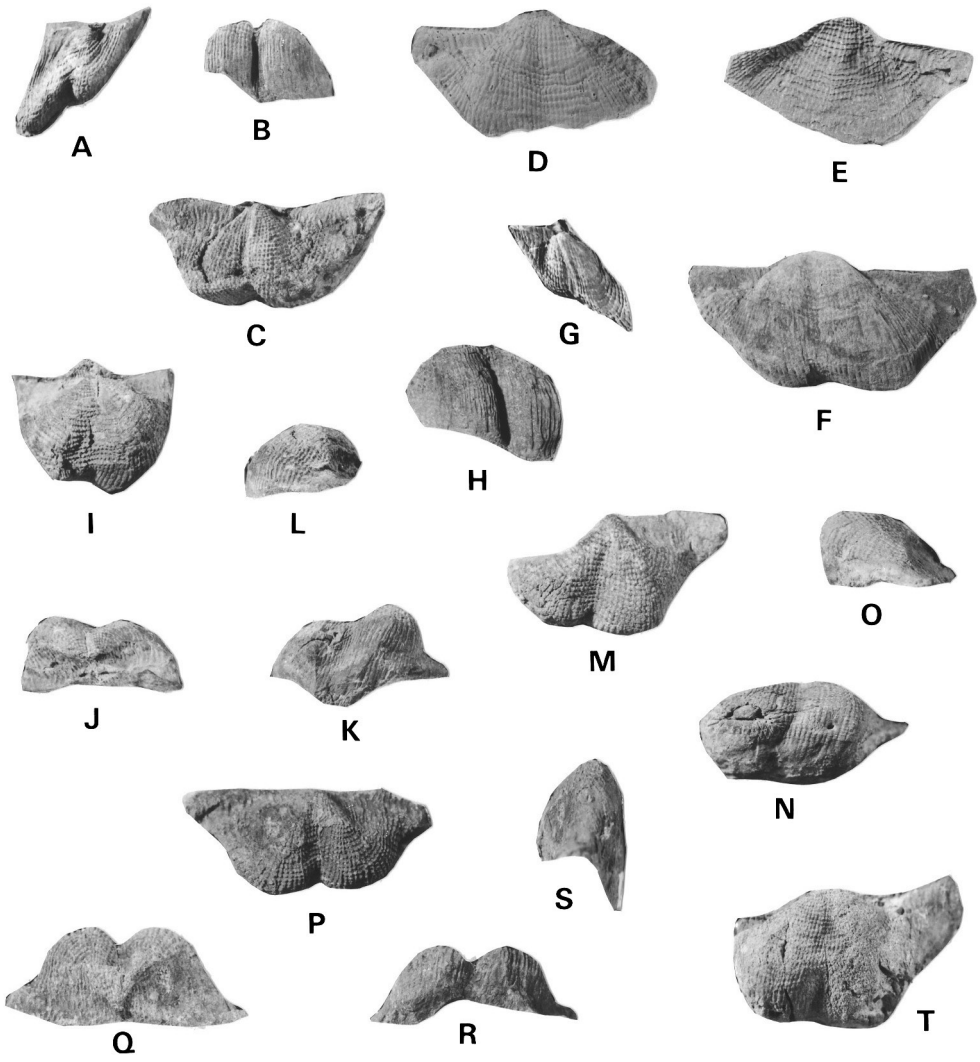

Fig. 4. *Lamnimargus peregrinus* (Fredericks) from the Upper Permian Toyoma Formation of Maeda, Ofunato City, Iwate Prefecture. A, B: dorsal (A) and anterior (B) views of external mould of dorsal valve, NU-B1064, C: external mould of dorsal valve, NU-B1071, D-F: external latex cast (D), external mould (E) and internal mould (F) of ventral valve, NU-B1067, G, H: dorsal (G) and anterior (H) views of external mould of dorsal valve, NU-B1070, I-L: dorsal (I), posterior (J), anterior (K) and lateral (L) views of external mould of dorsal valve, NU-B1072, M-O: dorsal (M), anterior (N) and lateral (O) views of external mould of dorsal valve, NU-B1073, P-S: dorsal (P), posterior (Q), anterior (R) and lateral (S) views of external mould of dorsal valve, NU-B1074, T: external mould of dorsal valve, NU-B1075. (All × 1).

but no spine bases entirely.

Internally, ventral valve having a pair of raised, elongate and smooth adductor scars, and impressed, wide, oval and striated diductor scars; marginal ridge highly developed at anterior portion. Dorsal valve interior with a cardinal process, followed by thin median septum; brachial ridges strongly developed; adductor scars elongate, smooth; numerous pits over anterior portion of visceral disc.

Remarks.— These specimens are referred to *Lamnimargus peregrinus* (Fredericks, 1924), originally described by Fredericks (1924) from the Middle Permian (correlated with the upper Wordian-Capitanian) Chandalaz Formation of the Vladivostok area, South Primorye, eastern Russia, on account of size, shape and external ornament of the ventral valves.

The type species, *Lamnimargus himalayensis* (Diener, 1899, p. 39, pl. 2, figs. 1-7; pl. 6, figs. 1, 2) differs from the present species in its coarser costellae on the both valves and much larger, prominent and convex ears on the ventral valve.

Lamnimargus japonicus (Tazawa, 1975, p. 636, pl. 2, figs. 3-6; pl. 3, figs. 1-4), from the Upper Permian (Changhsingian) of the Nabekoshiyama area, South Kitakami Belt, northeast Japan, is clearly distinguished from *Lamnimargus peregrinus*, by its smaller size and finer reticulate ornament on the visceral disc of both valves.

Distribution.—Middle Permian (Wordian-Capitanian) of North China (Inner Mongolia), Northeast China (Heilongjiang), eastern Russia (South Primorye); Upper Permian (Wuchiapingian) of eastern Russia (South Primorye); Upper Permian (Changhsingian) of northeast Japan (Ofunato in the South Kitakami Belt).

Acknowledgements

I would like to thank Masayuki Ehiro of the Tohoku University Museum, Sendai and Yukio Miyake of Ichinomiya-cho, Takayama City, Gifu Prefecture for sending me the fossil specimens. I also wish to thank Isao Niikawa of the Department of Geology, Faculty of Science, Niigata University for critical reading of the manuscript.

References

Chao, Y.T., 1927, Productidae of China, Pt. 1 Producti. *Palaeont. Sinica, Ser. B*, **5**, fasc. 2, 1-244.

Diener, C., 1899, Anthracolithic fossils of Kashmir and Spiti. *Palaeont. Indica, Ser. 15,* **1**, pt. 2, 1-95.

Diener, C., 1903, Permian fossils of the Central Himalayas. *Palaeont. Indica, Ser. 15*, **1**, pt. 5, 1-204.

Diener, C., 1915, The Anthracolithic faunae of Kashmir, Kanaur and Spiti. *Palaeont. Indica, N. S.*, **5**, 1-135.

Duan, C. and Li, W., 1985, Brachiopoda. *In* Ding, Y., Xia, G., Duan, C., Li, W., Liu, X. and Liang, Z., Study on the Early Permian stratigraphy and fauna in Zhesi district, Nei Mongol Zizhiqu (Inner Mongolia). *Bull. Tianjin Inst. Geol. Min. Res*., no. 10, 99-145, 199-214. (in Chinese)

Ehiro, M., 1996, Latest Permian ammonoid *Paratirolites* from the Ofunato district, South Kitakami Massif, Northeast Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 184, 592-596.

Ehiro, M., 1997, Ammonoid palaeobiogeography of the South Kitakami Palaeoland and palaeogeography of eastern Asia during Permian to Triassic time. *In* Jin, Y. and Dineley, D., eds., *Proceedings of the 30th International Geological Congress, Beijing, China, 4-14 August 1996, Vol. 12. Palaeontology and Historical Geology*, VSP, Utrecht, 18-28.

Fredericks, G., 1916, Paleontologicheskiya zametki, 2. O nekotorykh verkhnepaleozoyskikh brakhiopodakh Evrazii. *Tr. Geol. Kom., N. S.*, **156**, 1-87. (in Russian)

Fredericks, G., 1924, Ussuriyskiy verkhniy paleozoy, 1. Brachiopoda. *Mater. Geol. Polezn. Iskopaem. Dalnego Vostoka*, no. 28, 1-52. (in Russian)

Fredericks, G., 1925, Verkhniy paleozoy, 2. Permskie brakhiopody s mysa Kaluzina. *Mater. Geol. Polezn. Iskopaem. Dalnego Vostoka,* no. 40, 1-28. (in Russian)

Gray, J.E., 1840, *Synopsis of the contents of the British Museum, 42nd edition*. British Museum, London, 370 p.

Gupta, V.J. and Waterhouse, J.B., 1979, Permian invertebrate faunas from the *Lamnimargus himalayensis* Zone of Spiti and Ladakh regions, northwest India. *In* Gupta, V.J. et al., eds., *Upper Palaeozoic of the Himalaya*, *Contributions to Himalayan Geology, Vol. 1,* Hindustan Pub., Dehli, 5-19.

Kotlyar, G.V. and Zakharov, Yu.D., 1989, *Pozdnepermskiy etap evolyutsii organicheskogo mira. Midiyskiy yarus SSSR*. Nauka, Leningrad, 182 p. (in Russian)

Lee, L. and Gu, F., 1976, Carboniferous and Permian Brachiopoda. *In* Geological Bureau of Nei Mongol and Geological Institute of Northeast China, eds., *Palaeontological atlas of Northeast China: Nei Mongol, Pt. 1. Palaeozoic volume*, Geol. Pub. House, Beijing, 228-306. (in Chinese)

Lee, L., Gu, F. and Su, Y., 1980, Carboniferous and Permian Brachiopoda. *In* Shenyang Institute of Geology and Mineral Resources, ed., *Palaeontological atlas of Northeast China, Pt. 1. Palaeozoic volume,* Geol. Pub. House, Beijing, 327-428. (in Chinese)

Licharew, B.K. and Kotlyar, G.V., 1978, Permskie brakhiopody Yuzhnogo Primorya. *In* Popeko, L.L., ed., *Verkhniy Paleozoy Severo-Vostochnoy Azii*, DVNTS AN SSSR, Vladivostok, 63-75. (in Russian)

Minato, M., Hunahashi, M., Watanabe, J. and Kato, M., 1979, *Variscan geohistory of northern Japan: The Abean Orogeny.* Tokai Univ. Press, Tokyo, 427 p.

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.

Muir-Wood, H.M. and Oakley, K.P., 1941, Upper Palaeozoic faunas of North Sikkim. *Palaeont. Indica, N. S.*, **31**, 1-91.

Nakazawa, K., 1991, Mutual relation of Tethys and Japan during Permian and Triassic time viewed from bivalve fossils. *Saito Ho-on Kai Spec. Pub.*, no. 3, 3-20.

Nakazawa, K., 1998, Uppermost Permian bivalve fossils from the Southern Kitakami Mountains. *Earth Science (Chikyu Kagaku)*, **52**, 51-54. (in Japanese)

Sarytcheva, T.G. and Sokolskaya, A.N., 1959, O klassifikatsin lozhnoporistykh brakhiopod. *Doklady, Akad. Nauk SSSR*, **125**, 181-184. (in Russian)

Schuchert, C., 1929, Classification of brachiopod genera, fossil and recent. *In* Pompeckj, J.F., ed., *Fossilium Catalogus, Vol. 1*, Junk, Berlin, 10-25.

Shen, S.Z., Archbold, N.W. and Shi, G.R., 2000, Changhsingian (Late Permian) brachiopod palaeobiogeography. *Historical Biology*, **15**, 121-134.

Shen, S.Z., Archbold, N.W., Shi, G.R. and Chen, Z.Q., 2000, Permian brachiopods from the Selong Xishan section, Xizang (Tibet), China, Part 1: Stratigraphy, Strophomenida, Productida and Rhynchonellida. *Geobios*, **33**, 725-752.

Shen, S.Z., Shi, G.R. and Archbold, N.W., 2003, A Wuchiapingian (Late Permian) brachiopod fauna from an exotic block in the Indus-Tsangpo suture zone, southern Tibet, and its

palaeobiogeographical and tectonic implications. *Palaeontology*, **46**, 225-256.
Shimizu, D., 1961, Brachiopod fossils from the Permian Maizuru Group. *Mem. Coll. Sci., Univ. Kyoto, Ser. B*, **27**, 309-351.
Shimizu, D., 1981, Upper Permian brachiopod fossils from Guryul Revine and the Spur three kilometres north of Barus. *Palaeont. Indica, N. S.*, **46**, 67-85.
Stehli, F.G., 1954, Lower Permian Brachiopoda of the Sierra Diablo. *Bull. Amer. Mus. Nat. Hist.*, **105**, 262-358.
Tazawa, J., 1975, Uppermost Permian fossils from the southern Kitakami Mountains, northeast Japan. *Jour. Geol. Soc. Japan*, **81**, 629-640.
Tazawa, J., 1976, The Permian of Kesennuma, Kitakami Mountains: A preliminary report. *Earth Sci. (Chikyu Kagaku)*, **30**, 175-185.
Tazawa, J., 2000, Permian brachiopod faunas and pre-Neogene tectonics in the Inner Side of Southwest Japan. *Monograph (Chidanken Senpo)*, no. 49, 5-22. (in Japanese)
Tazawa, J., 2006a, *Lamnimargus, Megousia* and *Eolyttonia* (Productida, Brachiopoda) from the Upper Permian (Changhsingian) of the Kawahigashi area, Maizuru Belt, southwest Japan, and their palaeobiogeographical significance. *Sci. Rep., Niigata Univ. (Geol.)*, no. 21, 1-18.
Tazawa, J., 2006b, Late Permian Boreal-Tethyan mixed brachiopod fauna from the Maizuru Belt, southwest Japan: Fossil evidence for the tectono-sedimentological setting of the Maizuru Group. *Jour. Geol. Soc. Japan*, **112**, 510-518. (in Japanese)
Tazawa, J., 2007, Middle Permian brachiopod faunas of Japan and their significance for understanding the Palaeozoic-Mesozoic tectonics of the Japanese Islands. *In* Wong, Th.E., ed., *Proceedings of the XVth International Congress on Carboniferous and Permian Stratigraphy*, Roy. Netherlands Acad. Arts Sci., Amsterdam, 565-573.
Ustritsky, V.I., 1963, Phylum Brachiopoda. *In* Ustritsky, V.I. et al., *Permian stratigraphy and fauna of the Beishan area, western Gansu*, Chinese Technology Press, Beijing, 6-35. (in Chinese)
Waagen, W., 1883, Salt Range fossils, 1. Productus-Limestone fossils: Brachiopoda. *Palaeont. Indica, Ser. 13*, **1**, pt. 4, fasc. 2, 391-546.
Wang, C. and Zhang, S., 2003, *Zhesi brachiopod fauna*. Geol. Pub. House, Beijing, 210 p. (in Chinese)
Waterhouse, J.B., 1970, Permian brachiopod *Retimarginifera* n. gen. n. sp. from the Byro Group of Carnarvon Basin, Western Australia. *Jour. Roy. Soc. West. Aust.*, **53**, 120-128.
Waterhouse, J.B., 1975, New Permian and Triassic brachiopod taxa. *Pap. Dep. Geol. Univ. Qd.*, **7**, 1-23.
Waterhouse, J.B., 1978, Permian Brachiopoda and Mollusca from north-west Nepal. *Palaeontographica, Abt. A*, **160**, 1-175.
Waterhouse, J.B. and Gupta, V.J., 1983, A faunule from the *Lamnimargus himalayensis* Zone in the Upper Shyok Valley, southern Karakorum Range. *In* Gupta, V.J. et al., eds., *Stratigraphy and structure of Kashmir and Ladakh Himalaya*, *Contribution to Himalayan Geology, Vol. 2*, Hindustan Pub., New Delhi, 234-245.
Zhang (Chang), S. and Jin (Ching), Y., 1976, Late Paleozoic brachiopods from the Mount Jolmo Lungma region. *In* Xizang Scientific Expedition Team of Chinese Academy of Sciences, ed., *A report of Scientific Expedition in the Mount Jolmo Lungma region (1966-1968), Pt. 2,* Science Press, Beijing, 159-242. (in Chinese)
Ziegler, A.M., Hulver, M.L. and Rowley, D.B., 1997, Permian world topography and climate. *In* Martini, I.P., ed., *Late glacial and postglacial environmental changes—Quaternary, Carboniferous-Permian and Proterozoic*. Oxford Univ. Press, New York, 1-37.