Lamnimargus, Megousia and *Eolyttonia* (Productida, Brachiopoda) from the Upper Permian (Changhsingian) of the Kawahigashi area, Maizuru Belt, southwest Japan, and their palaeobiogeographical significance

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Abstract

Some productoid brachiopods of the Late Permian Kawahigashi fauna, originally described by Shimizu (1961a) from the upper part of the Maizuru Group in the Kawahigashi area, Kyoto Prefecture, Maizuru Belt, southwest Japan, are herein reexamined and systematically redescribed as *Lamnimargus japonicus*, *Megousia* sp. and *Eolyttonia* sp. All of the brachiopods, as well as the Middle to Late Permian foraminifers from the upper Maizuru Group in the Kawahigashi area, are reworked fossils, derived from shallow marine continental shelf to a deep-sea basin by sediment-gravity flows in the Late Permian (Changhsingian). The Kawahigashi fauna is a typical Boreal-Tethyan mixed fauna, with *Lamnimargus* and *Megousia* as the Boreal elements, and *Eolyttonia* as the Tethyan element. The Maizuru Belt of southwest Japan, including the Kawahigashi area, was probably located in the transitional zone of the Boreal-Tethyan realms, which was developed along the eastern margin of North China (Sino-Korea) in the Late Permian (Changhsingian).

Key words: Boreal-Tethyan mixed fauna, brachiopod, Changhsingian, *Eolyttonia*, *Lamnimargus*, Maizuru Belt, *Megousia*

Introduction

Late Permian brachiopod faunas of the Maizuru Group, containing totally 53 species in 26 genera, have hitherto been described by Mashiko (1934), Imamura (1953), Shimizu (1961a, b;

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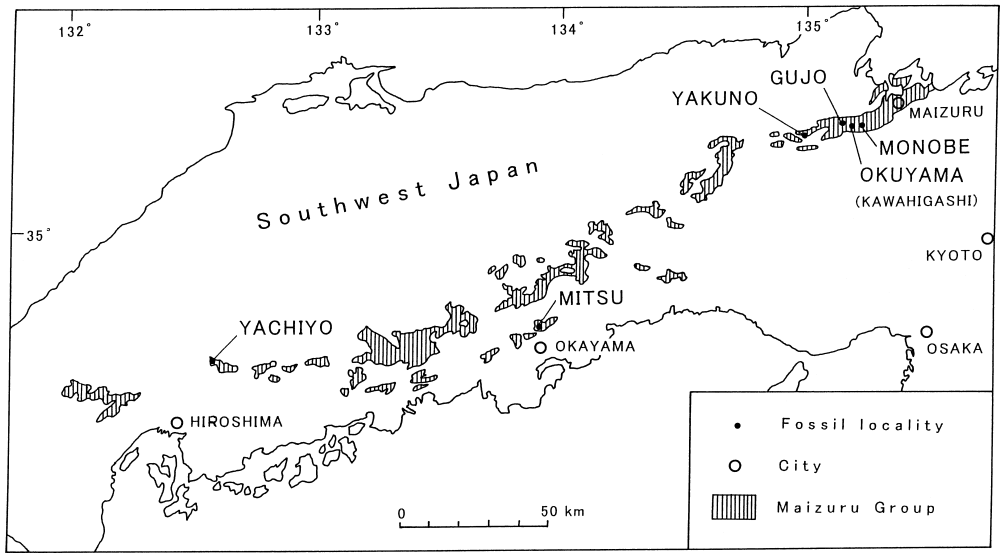

Fig. 1. Simplified geological map of southwest Japan, showing the distribution of the Permian Maizuru Group and the brachiopod fossil localities (modified and adapted from Hayasaka, 1990).

1963) and Yanagida (1993) from several localities in the Maizuru Belt, southwest Japan (Fig. 1). The Kawahigashi fauna, originally described by Shimizu (1961a) from the upper part of the Maizuru Group in the Kawahigashi and Yakuno areas in Kyoto Prefecture, is the largest one among these faunas, and it consists of 20 species in 10 genera (Table 1). The age of the upper Maizuru Group is regarded as a Late Permian (Changhsingian) based on the Middle to Late Permian reworked foraminifer fossils (Kobayashi, 2003) and the brachiopod faunal affinity with the Changhsingian fauna, described by Tazawa (1975) from the upper Toyoma Formation of Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan.

In the present study, the following four productoid species among the Kawahigashi fauna are reexamined and redescribed: *Productus* (*Dictyoclostus*) *gratiosus* Waagen, 1884 [=*Lamnimargus japonicus* (Tazawa, 1975)], *Productus* (*Dictyoclostus*) sp. [=*Lamnimargus japonicus* (Tazawa, 1975)], *Linoproductus interruptus* Huang, 1932 [=*Megousia* sp.] and *Eolyttonia nakazawai* Shimizu, 1961 [=*Eolytonia* sp.] (see Table 1). In addition, the Late Permian palaeogeography and palaeobiogeography of the Maizuru Belt and closely related South Kitakami Belt are discussed.

The brachiopod specimens treated in this study are registered and housed in the Kyoto University Museum, Kyoto.

Table 1. Permian brachiopod species of the Kawahigashi fauna, originally described by Shimizu (1961a), and partly revised by the present author.

Shimizu (1961a)	This study
Chonetina substrophomenoides (Huang)	
C. cf. *strophomenoides (Waagen)*	
C. *matsushitai* Shimizu	
Lissochonetes bipartita (Waagen)	
L. *morahensis* (Waagen)	
L. *cf. avicula* (Waagen)	
L. sp.	
Productus (*Dictyoclostus*) *gratiosus* Waagen	*Lamnimargus japonicus* (Tazawa)
P. (*D.*) cf. *margaritatus* Mansuy	
P. (*D.*) sp.	*Lamnimargus japonicus* (Tazawa)
Linoproductus kiangsiensis (Kayser)	
L. *interruptus* Huang	*Megousia* sp.
Aulosteges dalhousi Davidson	
Eolyttonia nakazawai Shimizu	*Eolyttonia* sp.
Derbyia altestriata Waagen	
D. cf. *altestriata* Waagen	
D. cf. *grandis* Waagen	
D. *hemispaerica* var. *radiata* Reed	
D. sp.	
Hustedia grandicosta (Davidson)	
H. *indica* (Waagen)	

Distribution of *Lamnimargus*, *Megousia* and *Eolyttonia*

The Kawahigashi fauna includes three productoid species, *Lamnimargus japonicus* (Tazawa, 1975), *Megousia* sp. and *Eolyttonia* sp. The stratigraphical and geographical distributions of species belonging to the genera *Lamnimargus, Megousia* and *Eolyttonia* are summarized below.

***Lamnimargus*:** The genus *Lamnimargus* was proposed by Waterhouse (1975, p. 10) with *Marginifera himalayensis* Diener, 1899, as type species. This genus contains two species, *L. himalayensis* (Diener, 1899) and *L. japonicus* (Tazawa, 1975). The stratigraphical and geographical distributions of these species are as follows:

Lamnimargus himalayensis (Diener, 1899): Middle Permian (Roadian-Wordian) of the Velebit Mts., Croatia (Sremac, 1986); Middle to Upper Permian (Roadian-Wuchiapingian) of the Mt. Qomolangma region, Tibet (Zhang and Jin, 1976) and the Beishan area, Gansu, north China (Ustritsky, 1963); Upper Permian (Wuchiapingian) of the southern Karakorum Range (Waterhouse and Gupta, 1983), Kashmir (Diener, 1915; Shimizu, 1981), Ladakh, Panjab Himalayas (Gupta and Waterhouse, 1979), Spiti, Panjab Himalayas (Diener, 1899, 1903;

Gupta and Waterhouse, 1979), Nepal Himalayas (Diener, 1903; Waterhouse, 1978) and the Trudny Peninsula, South Primorye, eastern Russia (Kotlyar, 1989).

Lamnimargus japonicus (Tazawa, 1975): Upper Permian (Changhsingian) of Okuyama in the Kawahigashi area, Maizuru Belt, southwest Japan (Shimizu, 1961a; this study) and Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan (Tazawa, 1975, 1976; Minato et al., 1979).

***Megousia*:** The genus *Megousia* was proposed by Muir-Wood and Cooper (1960, p. 309) with *Megousia auriculata* Muir-Wood and Cooper, 1960, as type species. This genus contains more than 15 species. The stratigraphical and geographical distributions of these species are as follows:

Megousia weyprechti (Toula, 1873): Middle Permian (Roadian) of the Kanin Peninsula, northern Russia (Kalashnikov, 1993); Middle Permian (Wordian-Capitanian) of Spitsbergen (Toula, 1873, 1874, 1875; Wiman, 1914; Frebold, 1937; Gobbett, 1963; Sarytcheva, 1977; Malkowski, 1988; Nakamura et al., 1990, 1992); Middle to Upper Permian (Wordian-Wuchiapingian) of Novaya Zemlya, northern Russia (Kalashnikov and Ustritsky, 1981; Kalashnikov, 1986).

Megousia kulikii (Fredericks, 1915): Lower Permian (Artinskian-Kungurian) of the Pechora Basin, northern Russia (Fredericks, 1915; Solomina, 1960; Ifanova, 1972; Sarytcheva, 1977; Kalashnikov, 1983, 1986, 1993); Lower Permian (Kungurian) of Spitsbergen (Stepanov, 1937; Malkowski, 1988) and Timan, northern Russia (Barchatova, 1970).

Megousia yakutica (Licharew, 1934): Middle Permian (Roadian-Capitanian) of the Kolyma-Omolon region, northern Russia (Licharew, 1934; Sarytcheva, 1977); Middle Permian (Wordian) of the Taimyr Peninsula, northern Russia (Ustritsky and Tschernyak, 1963).

Megousia alata (Cooper, 1953): Middle Permian (Wordian) of western Sonora, Mexico (Cooper, 1953; Muir-Wood and Cooper, 1960).

Megousia aurita (Solomina, 1957): Lower Permian (Kungurian) of Pai Khoi, Pechora Basin, northern Russia (Solomina, 1957).

Megousia auriculata Muir-Wood and Cooper, 1960: Lower and Middle Permian (Sakmarian-Wordian) of West Texas (King, 1931; Muir-Wood and Cooper, 1960; Ferguson, 1969; Cooper and Grant, 1975); Upper Permian (Changhsingian) of Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan (Nakamura, 1972).

Megousia solita Waterhouse, 1968: Lower Permian (Kungurian) of New South Wales, eastern Australia (Waterhouse, 1968; Briggs, 1998) and Stephens Island, New Zealand (Briggs and Campbell, 1993).

Megousia koizumii Nakamura, 1972: Upper Permian (Wuchiapingian) of the Soma area, Abukuma Mts., South Kitakami Belt, northeast Japan (Tazawa and Gunji, 1982); Upper Permian (Wuchiapingian-Changhsingian) of the Takakurayama area, Abukuma Mts., South

Kitakami Belt, northeast Japan (Nakamura, 1972).

Megousia definita Cooper and Grant, 1975: Middle Permian (Wordian) of West Texas (Cooper and Grant, 1975).

Megousia flexuosa Cooper and Grant, 1975: Middle Permian (Wordian) of West Texas (Cooper and Grant, 1975).

Megousia mucronata Cooper and Grant, 1975: Middle Permian (Wordian) of West Texas (Cooper and Grant, 1975).

Megousia umbonata Cooper and Grant, 1975: Lower Permian (Artinskian-Kungurian) of West Texas (Cooper and Grant, 1975).

Megousia nakamurai Tazawa, 1975: Upper Permian (Changhsingian) of Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan (Tazawa, 1975, 1976; Minato et al., 1979).

Megousia pobedensis Kotlyar, 1978: Middle Permian (Capitanian) of South Primorye, eastern Russia (Licharew and Kotlyar, 1978).

Megousia crenulata Briggs, 1998: Lower Permian (Kungurian) of the Sydney Basin, eastern Australia (Briggs, 1998).

Megousia sp. indet.: Lower Permian (Artinskian-Kungurian) of east Greenland (Frebold, 1931) and Queensland, eastern Australia (Hill, 1950); Middle Permian (Roadian-Capitanian) of Spitsbergen (Frebold, 1937; Gobbett, 1963), Verkhoyansk, northern Russia (Abramov and Grigorjeva, 1988), Moribu, Hida Gaien Belt, central Japan (Tazawa, 2001b), east-central Alaska (Brabb and Grant, 1971), Axel Heiberg Island, Arctic Canada (Stehli and Grant, 1971) and Tasmania, southeast Australia (Waterhouse, 1968); Upper Permian (Wuchiapingian-Changhsingian) of Tsunemori in the Akiyoshi area, Akiyoshi Belt, southwest Japan (Yanagida, 1996) and the Takakurayama area, Abukuma Mts., South Kitakami Belt, northeast Japan (Nakamura, 1972); Upper Permian (Changhsingian) of Monobe in the Kawahigashi area, Maizuru Belt, southwest Japan (Shimizu, 1961a; this study).

***Eolyttonia*:** The genus *Eolyttonia* was erected by Fredericks (1924, p. 25) with *Oldhamina* (*Lyttonia*) *mira* Fredericks, 1916, as type species. More than 21 species of *Eolyttonia* have been described. The stratigraphical and geographical distributions of these species are as follows:

Eolyttonia mira (Fredericks, 1916): Middle Permian (Capitanian) of Vladivostok, South Primorye, eastern Russia (Fredericks, 1916, 1924, 1925).

Eolyttonia ivanovi (Fredericks, 1916): Middle Permian (Capitanian) of Vladivostok, South Primorye, eastern Russia (Fredericks, 1916, 1924, 1925).

Eolyttonia tastubaensis (Licharew, 1925): Lower Permian (Sakmarian?) of the southern Urals, northern Russia (Licharew, 1925).

Eolyttonia diabloensis (Stehli, 1954): Lower to Middle Permian (Artinskian-Wordian) of West Texas (King, 1931; Stehli, 1954; Cooper and Grant, 1974).

Eolyttonia fredericksi (King, 1931): Lower Permian (Artinskian) of West Texas (King, 1931; Cooper and Grant, 1974); Upper Permian (Wuchiapingian-Changhsingian) of Guangxi, south China (Huang, 1933).

Eolyttonia karawankensis Gauri and Ramovs, 1964: Upper Carboniferous (Gzhelian) of Jesenice, Karawanken Mts., Slovenia (Gauri and Ramovs, 1964).

Eolyttonia carnica Gauri, 1965: Upper Carboniferous (Kasimovian) of western Carnic Alps, Austria (Gauri, 1965).

Eolyttonia catilla Cooper and Grant, 1974: Lower Permian (Asselian) of West Texas (Cooper and Grant, 1974).

Eolyttonia chaotica Cooper and Grant, 1974: Lower Permian (Sakmarian-Artinskian) of Shaanxi, northwest China (Ding et al., 1989); Lower Permian (Kungurian) of West Texas (Cooper and Grant, 1974).

Eolyttonia circularis Cooper and Grant, 1974: Lower Permian (Sakmarian-Artinskian) of Shaanxi, northwest China (Ding et al., 1989); Lower Permian (Kungurian) of West Texas (Cooper and Grant, 1974).

Eolyttonia cornucopia Cooper and Grant, 1974: Lower Permian (Sakmarian) of West Texas (Cooper and Grant, 1974).

Eolyttonia gigantea Cooper and Grant, 1974: Lower Permian (Sakmarian) of West Texas (Cooper and Grant, 1974).

Eolyttonia parviconica Cooper and Grant, 1974: Lower Permian (Kungurian) of West Texas (Cooper and Grant, 1974).

Eolyttonia phialiforma Cooper and Grant, 1974: Lower Permian (Asselian) of West Texas (Cooper and Grant, 1974).

Eolyttonia pocillata Cooper and Grant, 1974: Lower Permian (Artinskian-Kungurian) of West Texas (Cooper and Grant, 1974).

Eolyttonia progressa Cooper and Grant, 1974: Middle Permian (Wordian) of West Texas (Cooper and Grant, 1974).

Eolyttonia wuchangensis (Lee and Gu, 1980): Middle Permian (Wordian-Capitanian) of Heilongjiang, northeast China (Lee and Gu in Lee et al., 1980).

Eolyttonia tumenlingensis (Lee and Gu, 1980): Middle Permian (Wordian-Capitanian) of Heilongjiang, northeast China (Lee and Gu in Lee et al., 1980).

Eolyttonia ovata (Lee and Gu, 1980): Middle Permian (Wordian-Capitanian) of Heilongjiang, northeast China (Lee and Gu in Lee et al., 1980).

Eolyttonia hemisphaerica (Lee and Gu, 1980): Middle Permian (Wordian-Capitanian) of Heilongjiang, northeast China (Lee and Gu in Lee et al., 1980).

Eolyttonia sp. indet.: Upper Carboniferous (Kasimovian) of the Cantabrian Mts., northwest Spain (Martinez Chacon and Winkler Prins, 1993); Lower Permian (Artinskian) of Ko Muk, southern Thailand (Grant, 1976); Lower to Middle Permian (Sakmarian-Capitanian) of West Texas (Cooper and Grant, 1974); Lower to Middle Permian (Kungurian-Roadian) of Hiyomo,

Mino Belt, central Japan (Tazawa and Shen, 1997); Middle Permian (Wordian) of Khao Hin Kling, north-central Thailand (Yanagida and Nakornsri, 1999); Middle Permian (Capitanian) of Bera, central Pahang, Malaysia (Sone et al., 2001); Upper Permian (Changhsingian) of Takauchi in the Yakuno area, Maizuru Belt, southwest Japan (Shimizu, 1961a; this study) and Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan (Tazawa, 1975, 1976; Minato et al., 1979).

Discussion

1. Age of the Kawahigashi fauna

Brachiopods of the Kawahigashi fauna occur from calcareous sandstone and conglomerate of the upper part of the Maizuru Group in the Kawahigashi area (Shimizu, 1961a; Shimizu et al., 1962). According to Kobayashi (2003), the upper Maizuru Group in the whole Maizuru Belt is composed of black shale with intercalations of sandstone, conglomerate and limestone, totally 100-700 m thick, and contains reworked foraminifer fossils of the Capitanian *Lepidolina* fauna, the Wuchapingian *Codonofusiella-Reichelina* fauna and the Changhsingian *Palaeofusulina-Colaniella* fauna. The brachiopods of the Kawahigashi fauna are also reworked fossils in the calcareous sandstone and sandstone matrix of conglomerate of the upper Maizuru Group. They were probably derived from shallow marine continental shelf to a deep-sea basin by sediment-gravity flows in the Late Permian, as suggested by Kobayashi (2003).

The brachiopod species, *Lamnimargus himalayensis*, *Megousia* sp. and *Eolyttonia* sp. have been described by Tazawa (1975) from the upper part of the Toyoma Formation of Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan. The upper Toyoma Formation of Mt. Nabekoshiyama mostly consists of black shale with subordinate sandstone, conglomerate and limestone, and contains reworked foraminifer fossils of the Changhsingian *Colaniella parva* fauna (Tazawa, 1975; Ishii et al., 1975; Kobayashi, 2002). It is noteworthy that both of the upper Maizuru Group in the Kawahigashi area and the upper Toyoma Formation in the Kesennuma area resemble each other in lithology and fossil contents.

From the above evidence, the upper Maizuru Group of the Kawahigashi area, Maizuru Belt can be correlated with the upper Toyoma Formation of Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt. Therefore, the age of the Kawahigashi fauna is regarded as a Late Permian (Changhsingian), although it contains reworked fossils of the Middle to Late Permian foraminifers and brachiopods.

2. Palaeobiogeography of the Kawahigashi fauna

Fig. 2 shows the geographical distribution of the genera *Lamnimargus*, *Megousia* and *Eolyttonia* in the Permian. *Lamnimargus* is distributed in the Middle to Upper Permian (Roadian-Changhsingian), mostly the Upper Permian (Wuchiapingian), of southern Europe

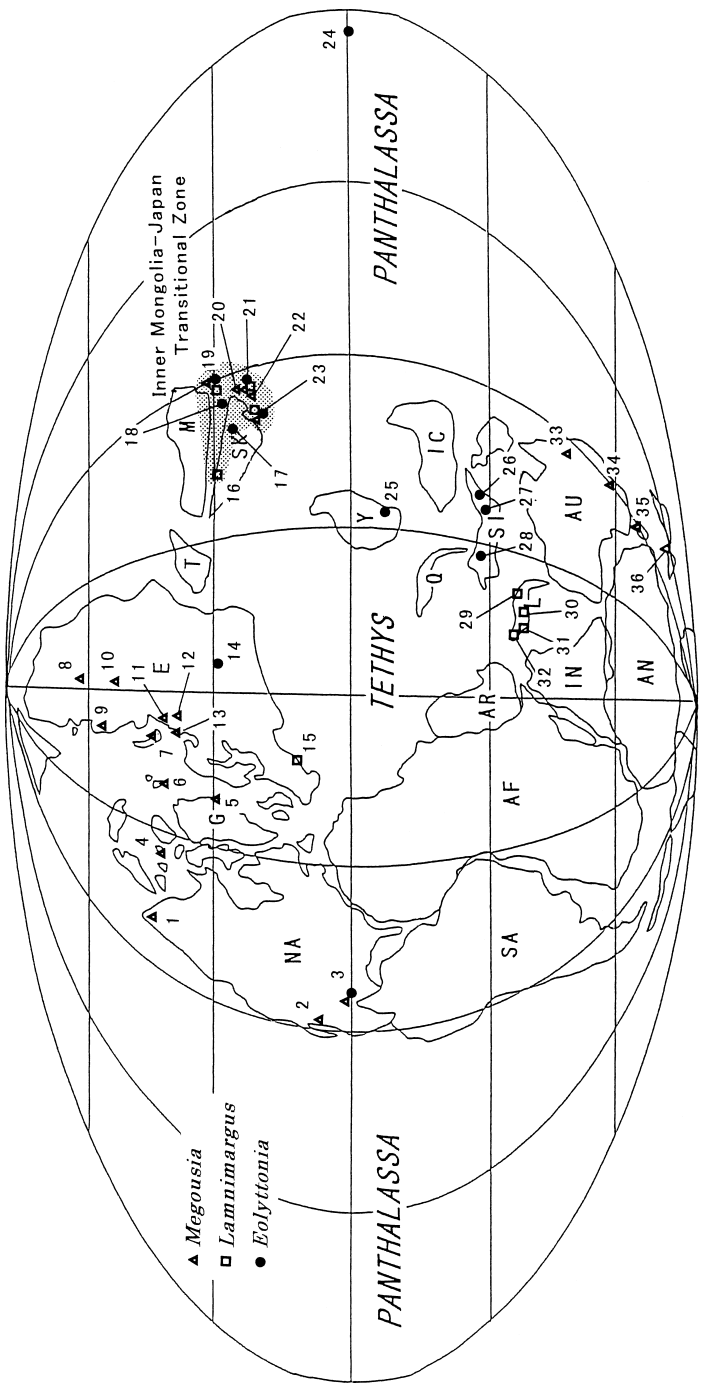

Fig. 2. Geographical distribution of *Megousia*, *Lamnimargus* and *Eolyttonia* in the Permian (plotted on the base map by Ziegler et al., 1997). Stippling indicates a Boreal-Tethyan mixed zone "Inner Mongolia-Japan Transitional Zone". 1: east-central Alaska, 2: western Sonora, 3: West Texas, 4: Axel Heiberg Island, 5: east Greenland, 6: Spitsbergen, 7: Novaya Zemlya, 8: Kolyma-Omolon, 9: Taimyr Peninsula, 10: Verkhoyansk, 11: Pai Khoi, Pechora Basin, 12: Timan, 13: Kanin Peninsula, 14: southern Urals, 15: Croatia, 16: Gansu, 17: Shaanxi, 18: Heilongjiang, 19: South Primorye, 20: Hida Gaien, 21: Maizuru, 22: Akiyoshi, 23: South Kitakami, 24: Mino, 25: Guangxi, 26: central Pahang, 27: Ko Muk, 28: Khao Hin Kling, 29: Qomolangma, 30: Nepal Himalayas, 31: Panjab Himalayas, 32: Karakorum, Kashmir, 33: Queensland, 34: Sydney Basin, 35: Tasmania, 36: Stephens Island, AF: Africa, AN: Antarctica, AR: Arabia, AU: Australia, E: Europe, G: Greenland, IC: Indochina, IN: India, L: Lhassa, M: Mongolia, NA: North America, Q: Qiangtang, SA: South America, SI: Sibumasu, SK: Sino-Korea, T: Tarim, Y: Yangtze.

(Croatia), Kashmir, Karkorum, Himalayas, Tibet, north China (Gansu), Japan (Maizuru and South Kitakami Belts) and eastern Russia (South Primorye). *Megousia* has been known from the Lower to Upper Permian (Sakmarian-Changhsingian), mostly the Lower to Middle Permian (Kungurian-Capitanian), of Greenland, Spitsbergen, northern Russia (Novaya Zemlya, Kanin Peninsula, Timan, Pechora Basin, Pai Khoi, Taimyr Peninsula, Verkhoyansk, Kolyma-Omolon), eastern Russia (South Primorye), Japan (Akiyoshi, Maizuru, Hida Gaien and South Kitakami Belts), Alaska, Arctic Canada (Axel Heiberg Island), Mexico (western Sonora), U.S.A. (West Texas), eastern Australia (Queensland and New South Wales), Tasmania and New Zealand. *Eolyttonia* is distributed in the Upper Carboniferous (Kasimovian) to the Upper Permian (Changhsingian), mostly the Lower to Middle Permian (Sakmarian-Capitanian), of southern Europe (Spain, Austria and Slovenia), Russia (southern Urals and South Primorye), Southeast Asia (Malaysia and Thailand), China (Shaanxi and Heilongjiang), Japan (Maizuru, Mino and South Kitakami Belts) and North America (West Texas).

The Kawahigashi fauna is a Boreal-Tethyan mixed fauna, because *Lamnimargus* and *Megousia* are the Boreal elements and *Eolyttonia* is the Tethyan element. This fauna is correlated with the Changhsingian Nabekoshiyama fauna from the upper Toyoma Formation of Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan. Therefore, the Kawahigashi and Kesennuma areas were probably located at the eastern margin of North China (Sino-Korea), i.e., the Inner Mongolia-Japan Transitional Zone of Tazawa (1991, 2001a) in the Late Permian (Changhsingian). The Yachiyo fauna, described by Yanagida (1993) from the Karita Formation of the Yachiyo area, Hiroshima Prefecture, Maizuru Belt, is also a Late Permian (Wuchiapingian) Boreal-Tethyan mixed fauna, containing a Boreal-type genus *Spiriferella* and some Tethyan-type genera such as *Oldhamina* and *Leptodus*. This fauna was probably located between the Kawahigashi and Kesennuma areas in the Inner Mongolia-Japan Transitional Zone. The reconstruction map of the Wuchiapingian by Shen and Shi (2000), and the Changhsingian by Shen et al. (2000) are not correct on the location of the Maizuru Belt. They misunderstood the Wuchiapingian Yachiyo fauna and the Changhsingian Kawahigashi fauna as the Tethyan faunas and placed them on the equatorial region, i.e., the Cathaysian Province of Shen et al. (2000). However, both of the Yachiyo and Kawahigashi faunas are evidently mixture of Boreal and Tethyan elements, and they belong to the Boreal-Tethyan transitional zone, i.e., the Inner Mongolia-Japan Transitional Zone.

Recently Kobayashi (1999, 2003) mentioned that the Maizuru Belt was located on the deep-sea basin near the eastern margin of South China (Yangtze) in Late Permian from foraminifer palaeobiogeographical data. The foraminifer data are, however, almost lacking informations about the Boreal regions, and they seem to be inadequate for reconstruction of the Late Permian palaeobiogeography of the world including the Maizuru Belt.

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Marginiferoidea Stehli, 1954
Family Paucispiniferidae Muir-Wood and Cooper, 1960
Subfamily Paucispiniferinae Muir-Wood and Cooper, 1960
Genus *Lamnimargus* Waterhouse, 1975

Type species.—*Marginifera himalayensis* Diener, 1899, p. 39, pl. 2, figs. 1-7: pl. 6, figs. 1, 2.

Lamnimargus japonicus (Tazawa, 1975)
Fig. 3A-E

Productus (*Dictyoclostus*) *gratiosus* Waagen: Shimizu, 1961a, p. 323, pl. 15, figs. 19-21.
Productus (*Dictyoclostus*) sp. Shimizu, 1961a, p. 325, pl. 15, figs. 13-15.
Paramarginifera japonica Tazawa, 1975, p. 636, pl. 2, figs. 3-6; pl. 3, figs. 1-4; Tazawa, 1976, pl. 3, figs. 10, 15; Minato et al., 1979, pl. 71, figs. 3-6; pl. 72, figs. 1-4.

Material.—Four specimens, (1) external and internal moulds of a ventral valve, JP30089A-C; (2) external mould of a dorsal valve, JP30093; (3) fragments of external moulds of two dorsal valves, JP30094, 30095, from calcareous very coarse to granule sandstone of the Maizuru Group at Nomaru of Okuyama, Oe-cho, Kasa-gun, Kyoto Prefecture (Shimizu, 1961a, p. 324, 326).

Description.—Shell small in size for genus, transversely subquadrate in outline, widest at hinge; length 14 mm, width about 23 mm in the ventral valve specimen (JP30089A); length 15 mm, width about 34 mm in the dorsal valve specimen (JP30093). Ventral valve highly convex in lateral profile, strongly geniculated at anterior margin of visceral disc, having a long trail. Dorsal valve deeply concave in lateral profile, with nearly flattened visceral disc, strongly geniculated and followed by a long trail; ears large, prominent, slightly concave, and obscurely demarcated from visceral disc; fold narrow and low. External surface of dorsal valve reticulate on visceral disc; concentric rugae regularly developed, numbering 7-8 in 5 mm at nearly midvalve; costellae having a density of 8-9 per 5 mm at nearly midvalve; costellae only on trail. Interior of ventral valve with a pair of large, flabellate, and longitudinally striated diductor scars; adductor scars small, elongate-oval in shape, smooth and highly elevated from floor of visceral disc; marginal ridge developed just anterior margin of visceral disc.

Remarks.—Shimizu (1961a) described the ventral valve specimen (JP30089A-C) from Okuyama in the Kawahigashi area as *Productus* (*Dictyoclostus*) *gratiosus* Waagen, 1884, and

the dorsal valve specimens (JP30093-30095) from Okuyama as *Productus* (*Dictyoclostus*) sp. However, the former differs from *Transennatia gratiosa* (Waagen, 1884) in its larger dimensions and having a marginal ridge in the ventral valve. The latter differs from *Dictyoclostus* species by its much smaller and more transverse shell, and having large, prominent ears. These specimens are referred to *Lamnimargus japonicus* (Tazawa, 1975, p. 636, pl. 2, figs. 3-6; pl. 3, figs. 1-4) from the Upper Permian (Changhsingian) of Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt in size, shape, external ornament and internal structure of the shells, especially, a strong marginal ridge in the ventral valve, and large, prominent ears and reticulate ornament on the dorsal visceral disc.

The type species, *Lamnimargus himalayensis* (Diener, 1899), from the Upper Permian (Wuchiapingian) Kuling Shales of Spiti, Panjab Himalayas, differs from *L. japonicus* in its larger size and coarser reticulate ornament on the dorsal visceral disc.

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Anidanthinae Waterhuse, 1968
Genus *Megousia* Muir-Wood and Cooper, 1960

Type species.—*Megousia auriculata* Muir-Wood and Cooper, 1960, p. 310, pl. 113, figs. 1-11.

Megousia sp.
Fig. 3G-J

Linoproductus interruptus Huang: Shimizu, 1961a, p. 327, pl. 15, figs. 11, 12.

Material.—One specimen, external and internal moulds of a dorsal valve, JP30097A, B, from lense of calcareous silty shale in black shales of the Maizuru Group at Okushinjo, Monobe, Ayabe City, Kyoto Prefecture (Shimizu, 1961a, p. 314, 327).

Description.—Shell small in size for genus. Dorsal valve transversely subrectangular in outline, slightly concave on visceral disc and flattened on ears, deepest at umbonal and median regions and flattening marginally; hinge forming greatest width; length 8 mm, width more than 19 mm. External surface of dorsal valve ornamented with strong concentric lamellae and fine numerous capillae over visceral disc, capillae only on ears; numbering 5 lamellae, of which anterior 3 lamellae prominent; 11-12 capillae per 3 mm nearly midvalve. Interior of dorsal valve having a short-shafted bi- or trilobate cardinal process; median septum short; lateral ridges strong. Other internal structures not preserved.

Remarks.—The single specimen from Monobe in the Kawahigashi area was described and figured by Shimizu (1961a, p. 327, pl. 15, figs. 11, 12) as *Linoproductus interruptus* Huang, 1932 [=*Anidanthus interruptus* (Huang, 1932)]. He, however, overlooked the presence of

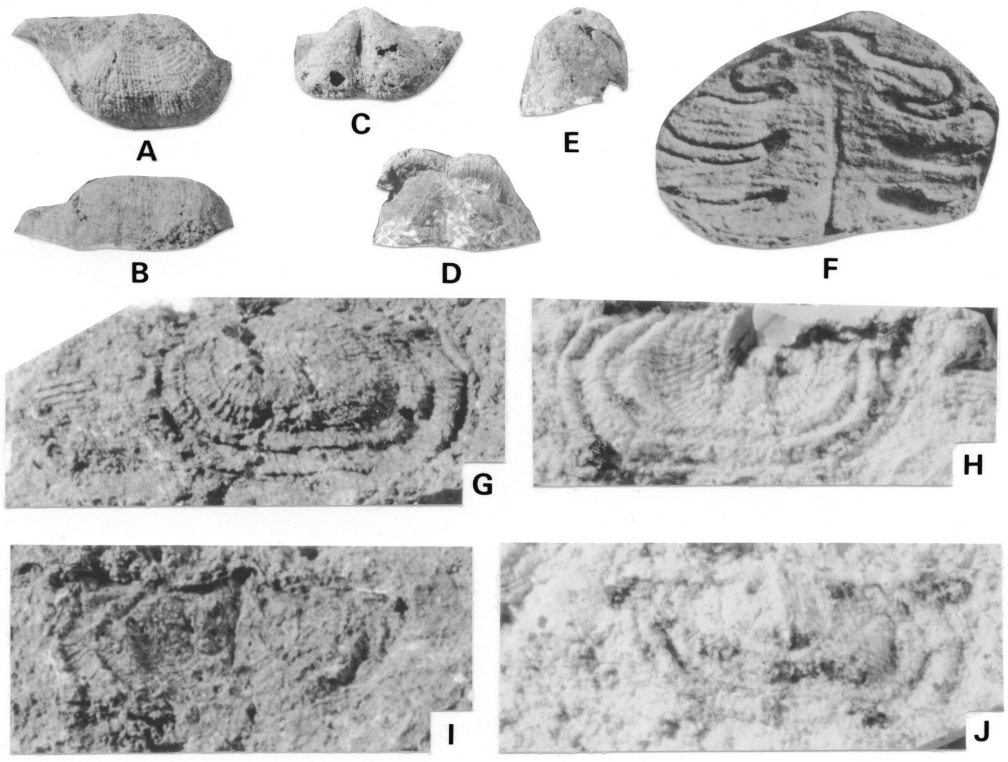

Fig. 3. Permian brachiopods of the Kawahigashi fauna, from the upper Maizuru Group in the Maizuru Belt, southwest Japan. A-E (×1), F-J (×3). A-E: *Lamnimargus japonicus* (Tazawa, 1975), A, B: dorsal and anterior views of an external mould of dorsal valve, JP30093, C, D, E: ventral, anterior and lateral views of an internal mould of ventral valve, JP30089A, F: *Eolyttonia* sp., ventral view of an internal mould of ventral valve, JP30100, G-J: *Megousia* sp., G, H: dorsal views of external mould and external latex cast of dorsal valve, JP30097A, I, J: dorsal views of internal mould and internal latex cast of dorsal valve, JP30097B.

large, flattened and capillate ear which is preserved on the dorsal external mould specimen (see Fig. 3G). This specimen is safely assigned to the genus *Megousia* by its size, shape and external ornament of dorsal valve, particularly by having large, flattened and capillate ears and prominent concentric lamellae on dorsal valve.

The Kawahigashi specimen superficially resembles *Megousia nakamurai* Tazawa (1975, p. 635, pl. 3, figs. 5, 6) from the Upper Permian (Changhsingian) of Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan, and the type species, *M. auriculata* Muir-Wood and Cooper, 1960, from the Wordian of the Glass Mountains, West Texas, but the material is too poor for comparison.

Suborder Lyttoniidina Williams, Harper and Grant, 2000
Superfamily Lyttonioidea Waagen, 1883
Family Lyttoniidae Waagen, 1883
Subfamily Lyttoniinae Waagen, 1883
Genus *Eolyttonia* Fredericks, 1924

Type species.—*Oldhamina* (*Lyttonia*) *mira* Fredericks, 1916, p. 74, pl. 2, figs. 8, 9; pl. 4, figs. 1a-c.

Eolyttonia sp.
Fig. 3F

Eolyttonia nakazawai Shimizu, 1961a, p. 330, pl. 15, fig. 22.

Material.—One specimen, internal mould of a ventral valve, JP30100, from calcareous sandstone of the Maizuru Group at Miyaodani of Takauchi, Yakuno-cho, Amata-gun, Kyoto Prefecture (Shimizu, 1961a, p. 331).

Description. See Shimizu (1961a, p. 330).

Remarks.—The single specimen from Takauchi in the Yakuno area is safely assigned to the genus *Eolyttonia* by its symmetrically arranged, thick, arcuate lateral septa with concave flat crests (=grooved angustilobate septa, Cooper and Grant, 1974, p. 414). The Yakuno species is, however, represented by a juvenile ventral valve, and comparison with the other species is difficult. It should be named as *Eolyttonia* sp., although Shimizu (1961a) established a new species, *Eolyttonia nakazawai* Shimizu, 1961 based on the present material.

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