# EARLY CARBONIFEROUS (MISSISSIPPIAN) BRACHIOPODS FROM THE SHITTAKAZAWA, ARISU AND ODAIRA FORMATIONS, SOUTH KITAKAMI BELT, JAPAN

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#### ABSTRACT

This study describes 56 species of early Carboniferous (Mississippian) brachiopods in 39 genera (including a new species, Levitusia elongata sp. nov.) from the Shittakazawa, Arisu and Odaira Formations in the central part (Shimoarisu, Yokota, Yahagi, Nisawa, Okuhinotsuchi and Shizu areas) of the South Kitakami Belt (southern Kitakami Mountains), northeastern Japan. On the basis of brachiopod biostratigraphy, the Shittakazawa Formation is correlated with the upper Tournaisian, the Arisu Formation with the lower Visean, and the Odaira Formation with the upper Visean. In terms of palaeobiogeography, the late Tournaisian (Shittakazawa) fauna is allied with those of the USA (Oklahoma), the UK (England), Poland, Belgium, central Russia (Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang); the early Visean (Arisu) fauna has a close affinity with those of the UK (England), Belgium, central Russia (southern Urals and Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang), particularly with Kazakhstan and northwestern China (Xinjiang); and the late Visean (Odaira) fauna exhibits affinities with assemblages of the UK (England), Belgium, central Russia (southern Urals), Kazakhstan and northwestern China (Xinjiang), particularly with Kazakhstan. Thus, the early Carboniferous (late Tournaisian-late Visean) brachiopod faunas of the central part of the South Kitakami Belt are allied with those of Kazakhstan and northwestern China (Xinjiang). The South Kitakami region was probably the eastern extension of the North China Provine, and was located at the eastern end of the Central Asian Orogenic Belt (CAOB), near and to the east of the North China Block as a shallow sea bordering a microcontinent during the early Carboniferous.

Key words: Arisu Formation, Brachiopoda, early Carboniferous, Odaira Formation, Shittakazawa Formation, South Kitakami Belt

田沢純一 (2020) 南部北上帯の尻高沢層,有住層,大平層から産出する前期石炭紀(ミシシッピー亜紀)腕 足類. 福井県立恐竜博物館紀要 19:11-88.

南部北上帯中央部(下有住・横田・矢作・荷沢・奥火の土・清水地域)の下部石炭系尻高沢層,有住層,大平層から産出する 39 属 56 種(1 新種 Levitusia elongata sp. nov. を含む)の前期石炭紀(ミシシッピー 亜紀)腕足類を記載した.これらの腕足類により,尻高沢層は Tournaisian 上部に,有住層は Visean 下部に,そして大平層は Visean 上部に対比される.古生物地理学的には,尻高沢フォー ナはアメリカ(オハイオ),イギリス,ポーランド,ベルギー,ロシア中央部(クズネック盆地),カザフスタン,中国西北部(新疆)の,有住フォーナはイギリス,ベルギー,ロシア中央部(ウラル山脈南部,クズネック盆地),カザフスタンおよび中国西北部(新疆)。とくにカザフスタンと中国西北部(新疆)の,また,大平フォーナはイギリス,ベルギー,ロシア中央部(ウラル山脈南部)。また,大平フォーナはイギリス,ベルギー,ロシア中央部(カラル山脈南部)の,また,大平フォーナはイギリス,ベルギー,ロシア中央部(ウラル山脈南部),カザフスタン,中国西北部(新疆),とくにカザフスタンの前期石炭紀腕足類フォーナと類縁がある.このことから,前期石炭紀(Tournaisian 後期~Visean 後期)に,南部北上地域は前期石炭紀腕足動物区の一つである北中国区に属し,おそらく中央アジア造山帯の東縁,北中国地塊の東方に存在したマイクロコンチネントの縁辺浅海域であったと推定される.

#### INTRODUCTION

Palaeozoic geography and biogeography of the South Kitakami Belt, northeastern Japan are important for

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understanding the geotectonic history of the South Kitakami Belt and the Japanese Islands in general. Brachiopoda is one of the most useful taxa for the Palaeozoic biogeography owing to its very abundant fossil records and being benthos. The Brachiopoda is useful also for biostratigraphy, because there are so numerous and diverse that it has been recorded more than two centuries. The method "assemblage zone" is useful for the Palaeozoic brachiopod biostratigraphy, although most of the brachiopod species have rather long ranges.

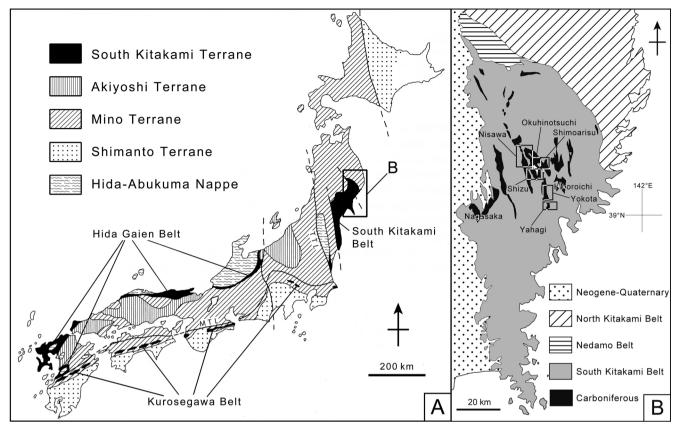


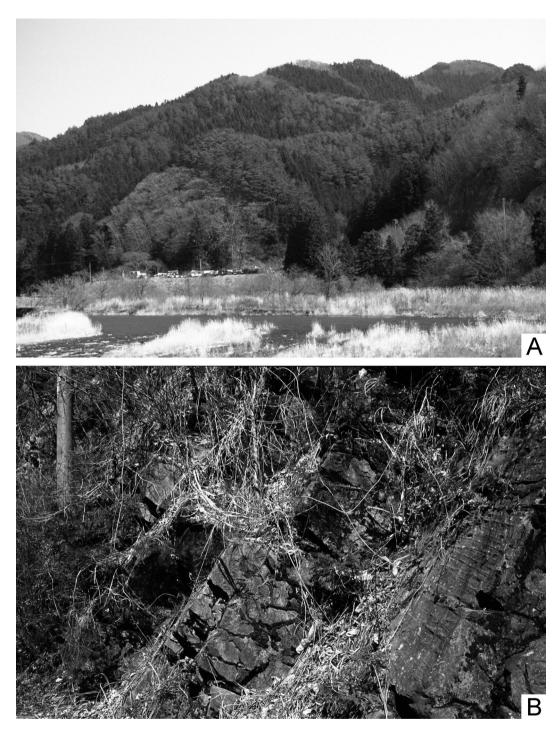
FIGURE 1. Map showing the location and geology of the Shimoarisu, Yokota, Yahagi, Nisawa, Okuhinotsuchi and Shizu areas in the South Kitakami Belt. (**A**) Geotectonic map of the Japanese Islands, showing the distribution of the South Kitakami Belt (after Tazawa, 2018c); (**B**) geotectonic map of the northeastern part of Honshu, Japan, showing the distribution of the Carboiferous rocks in the South Kitakami Belt (modified from Tazawa, 2018c).

Brachiopods are extremely common in the early Carboniferous (Mississippian) marine fauna of the South Kitakami Belt (southern Kitakami Mountains). Since the pioneering studies of Minato (1951, 1952), about 120 brachiopod species (in 65 genera) were described by Tachibana (1956, 1963, 1964, 1969, 1981), Minato and Kato (1977), Tazawa and Katayama (1979), Tazawa (1980, 1981b, 1984a, 1984b, 1985, 1989, 2006, 2017, 2018a), Tazawa and Kurita (1986, 2019a, 2019b), Tazawa and Miyake (2002), Chen and Tazawa (2007), Tazawa and Ibaraki (2009, 2019), Tazawa and Iryu (2019) and Tazawa et al. (2019). However, most of the species described in 1950–1980s need redescription on the revised stratigraphy of the lower Carboniferous formations of the South Kitakami Belt and on the new taxonomy of Brachiopoda.

The South Kitakami Belt contains well-exposed sections of lower Carboniferous (Mississippian) rocks. Brachiopods are common in the early Carboniferous marine fauna of the belt. The central part of the belt, including the Shimoarisu (Sumita-cho, Kesen-gun, Iwate Prefecture), Yokota (Yokota-cho, Rikuzentakata City, Iwate Prefecture), Yahagi (Yahagi-cho, Rikuzentakata City, Iwate Prefecture), Nisawa (Otomo-cho, Tono City, Iwate Prefecture), Okuhinotsuchi

(Sumita-cho, Kesen-gun, Iwate Prefecture) and Shizu (Sumita-cho, Kesen-gun, Iwate Prefecture) areas (Figs. 1 and 2), is an important and classical area for the lower Carboniferous stratigraphy and palaeontology of Japan as well as the South Kitakami Belt. Since the work of Endo (1924), the stratigraphy and palaeontology of the lower Carboniferous rocks and fossils in the central part of the belt have been extensively investigated (e.g., Minato, 1941, 1951, 1952; Minato et al., 1953, 1979b; Onuki, 1969; Minato and Kato, 1979; Tazawa and Katayama, 1979; Tazawa et al., 1981; Kawamura, 1985a, 1985b, 1985c; Kawamura et al., 1985, Tazawa, 2017; Tazawa and Kurita, 2019a; Tazawa and Iryu, 2019).

This paper is the third contribution of the series on the early Carboniferous brachiopods of the South Kitakami Belt. In the first of the series (Tazawa, 2018c), I described early Carboniferous brachiopods from the Hikoroichi Formation of the Hikoroichi area in the eastern part of the belt; the second contribution (Tazawa et al., 2019) addressed the brachiopods from the Karaumedate Formation in the Nagasaka area, western part of the belt. In the present study, I describe the early Carboniferous brachiopods from the Shittakazawa, Arisu and Odaira Formations in the central part of the South Kitakami Belt. I also discuss the stratigraphy and correlation of the lower



 $FIGURE\ 2.\ A\ distant\ view\ (\textbf{A})\ and\ a\ close\ view\ (\textbf{B})\ of\ locality\ KF159,\ outcrop\ of\ calcareous\ shale\ of\ the\ OD3\ Unit,\ upper\ Odaira\ Formation\ in\ Tairagai,\ Yokota-cho,\ Rikuzentakata\ City,\ Iwate\ Prefecture.$ 

Carboniferous formations, and the specific composition, age and palaeobiogeography of the brachiopod faunas.

PREVIOUS WORK

# Stratigraphy

Previous studies on the stratigraphy of the lower

			Minato (1941)	Minato (1951, 1952)	Minato et al. (1953)	Onuki (1956)	Takeda (1960)	Onuki (1969)	Minato et al. (1979b)	Tazawa and Katayama (1979)	Kawamura (1985a, b)	Tazawa (1985)	Kawamura et al. (1985)	Tazawa and Iryu (2019)	Tazawa and Kurita (2019)	Tazawa (This study)
		upper	Coral Limestone	Onimaru	Onimaru	Onimaru	Onimaru	Onimaru	Onimaru	Onimaru	Onimaru	Onimaru Formation	Onimaru Formation	Onimaru Formation	Onimaru Formation	Onimaru Formation
(m	Visean	dn	Coral Li	Series	Series	Formation	Series	Formation	Formation	Formation	Formation	Odaira	Odaira	Odaira Formation	Odaira Formation	Odaira Formation
(Mississippian)	Vis	lower										Formation	Formation	Arisu	Arisu	Arisu
		low		Ohdaira Series	Ohdaira Series	Ohdaira Formation		Odaira F.		Odaira Formation	Odaira Formation			Formation	Formation	Formation
nifer				Series			Ohdaira Series		Ohdaira F.				Arisu Formation			
lower Carboniferous	isian	upper	iira Series	Arisu Series	Arisu Series	Arisu Formation		Arisu Formation	Arisu F.	ıtion	Arisu Formation	Arisu Formation		Shittakazawa Formation	Shittakazawa Formation	Shittakazawa Formation
low	Tournaisian	lower	Ohdaira	Hikoroiti	Hikoroiti	Sasanohora Formation	Arisu Series		Hikoroichi Formation	Arisu Formation	Shittakazawa		Shittakazawa	takazawa		
		wol		Series	Series	Tyoanji Formation	Hikoroichi Series	Hikoroichi Formation		Ψ.	Formation Solution		Formation	Shit		

FIGURE 3. Comparison of stratigraphic schemes proposed for the lower Carboniferous formations in the Shimoarisu, Yokota and Yahagi areas, South Kitakami Belt.

Carboniferous formations in the central part of the South Kitakami Belt are summarized in Figs. 3 and 4. The modern stratigraphic studies started in 1941 when M. Minato published a paper, entitled "On the Lower Carboniferous deposits at Setamai, Kesen-gori, Iwate Prefecture". Since then, many studies have been investigated by Minato (1951, 1952), Minato et al. (1953, 1979b), Hirokawa and Yoshida (1954), Onuki (1956, 1969, 1981), Takeda (1960), Saito (1966, 1968), Moriai (1972), Minato and Kato (1979), Tazawa and Katayama (1979), Tazawa (1979, 1981b, 1985, 2006, 2017), Tazawa et al. (1981), Kawamura (1985a, 1985b, 1985c), Kawamura et al. (1985), Tazawa and Kurita (1986, 2019a, 2019b), Kawamura and Kawamura (1989), Tazawa and Ibaraki (2019) and Tazawa and Iryu (2019).

Minato (1950, 1955, 1966) emphasized the pre-Onimaru hiatus, a long hiatus between the upper Visean Onimaru Formation and the underlying formations, as evidence of the "Shizu Folding", one of the Palaeozoic orogenic events recorded in the South Kitakami Belt. But the Minato's proposal was denied litho- and bio-stratigraphically by Tazawa and Katayama (1979), Tazawa (1979, 1981b), Tazawa et al. (1981), Kawamura (1985a, 1985b, 1985c) and Kawamura et al. (1985) in the central part (Shimoarisu, Yokota, Yahagi, Nisawa, Okuhinotsuchi and Shizu areas) of the belt as well as the eastern part (Hikoroichi area; Mori and Tazawa, 1980; Tazawa, 1981a, 1984a, 1984b, 2018c; Kawamura, 1983), the western part (Nagasaka area; Tazawa and Osawa, 1979; Tazawa, 1980; Tazawa et al., 2019) and the southern part (Soma area; Tazawa et al., 1984; Tazawa, 1996) of the belt.

The lithostratigraphy of the lower Carboniferous formations

in the central part of the South Kitakami Belt was almost concluded by Kawamura (1985a, 1985b, 1985c) and Kawamura et al. (1985). However, the biostratigraphy of the formations was poor and remained in long time at the concept of Minato et al. (1953, 1979b) and Minato and Kato (1979), because of a paucity of fossil evidence. During the last few years, Tazawa and his collaborators clarified the age of the Shittakazawa Formation (Tazawa and Kurita, 2019a), the Arisu Formation (Tazawa and Kurita, 2019b; Tazawa and Ibaraki, 2019; Tazawa and Iryu, 2019) and the Odaira Formation (Tazawa, 2017) based on the brachiopods from the formations. Kawamura et al. (1985) also found that the uppermost part of the Odaira Formation was correlated with the upper Visean based on the corals, although the coral specimens have been described yet.

# **Palaeontology**

Studies on the invertebrate fossils from the Shittakazawa, Arisu and Odaira Formations are poor, except for the brachiopods. Until now only a few species of the corals, trilobites, crinoids and blastoids have been described: *Amplexus nipponensis* Minato and *Amplexus* sp. from the Arisu and Odaira Formations (Minato, 1952); *Sugiyamaella carbonarium* Yabe and Minato from the Odaira Formation (Yabe and Minato, 1944; Minato, 1951, 1952); *Palaeosmilia membiensis* Minato and Ogata from the Odaira Formation (Minato and Ogata, 1977); *Syringopora* sp. and *Phyllipsia?* sp. from the Odaira Formation (Minato, 1951); and *Platycrinus asiatica* Minato and Nucleocrinidae gen. et sp. indet. from the Arisu Formation (Minato, 1951). Kawamura et al. (1985) reported, but not

			Minato et al. (1953)	Hirokawa and Yoshida (1956)	Onuki (1956)	Onuki (1969)	Minato et al. (1979b)	Tazawa et al. (1981)	Kawamura (1985c)	Tazawa and Kurita (2019a, b)	Tazawa (This study)
		upper	Onimaru	Shiba	Onimaru	Onimaru	Onimaru	Onimaru Formation	Senbakaya Formation	Onimaru Formation	Onimaru Formation
(un	Visean	dn	Series	Formation	Formation	Formation	Formation	nation		Odaira Formation	Odaira Formation
ous (Mississippian)	Viso	lower				Odaira F.		Karoyama Formation	Karosawa Formation	Arisu Formation	Arisu Formation
lower Carboniferous	iisian	upper		Yonesato Formation		Arisu Formation			Kare	Shittakazawa Formation	Shittakazawa Formation
wol	Tournaisian	lower	Hikoroiti Series	Yones	Choanji Formation	Hikoroichi Formation	Hikoroichi Formation				

FIGURE 4. Comparison of stratigraphic schemes proposed for the lower Carboniferous formations in the Nisawa, Okuhinotsuchi and Shizu areas, South Kitakami Belt.

described, eight rugose coral species (Pseudouralinia tangpakouensis Yü, Siphonophyllia sp., Sugiyamaella sp., Caninophyllum? sp., Kueichouphyllum heishihkuanense Yü, Yuanophyllum kansuense Yü, "Lophophyllum" sp. and "Caninia" sp.) from the Odaira Formation.

In contrast, taxonomic studies on the brachiopods are plentiful. Minato (1951, 1952) described the following brachiopods (of 27 species in 17 genera) from the Arisu and Odaira Formations: Planoproductus gigantoides Minato, Pustula cf. tenuipustulata Thomas, Productus sp., Orthotetes keokuk (Hall), Orthotetes sp., Schellwienella izirii Minato, Schellwienella? sp., Derbyia depressa var. transversa Minato, Schizophoria resupinata (Martin), Actinoconchus lamellosa (Léveillé), A. cf. lamellosa (Léveillé), Cleiothyridina royssii (Léveillé), Spirifer kozuboensis Minato, Brachythyrina nagaoi Minato, Fusella nipponotrigonalis Minato, F. nipponotrigonalis var. minor Minato, Brachythyris aff. pinguis (Sowerby), Brachythyris? sp., Delthyris aff. clarksvillensis (Winchell), Kitakamithyris tyoanjiensis Minato, K. semicircularis Minato, Syringothyris jumonjiensis Minato, S. transversa Minato, S. kitakamiensis Minato, Syringothyris sp., Plicatosyrinx singulare

Minato and P.? kumanoi Minato. After that, brachiopods of 41 species in 27 genera were described from the Shittakazawa, Arisu and Odaira Formations by Minato and Kato (1977), Tazawa and Katayama (1979), Tazawa (1981b, 1985, 2006, 2017, 2018a), Tazawa and Kurita (1986, 2019a, 2019b), Tazawa and Ibaraki (2019) and Tazawa and Iryu (2019). The brachiopods are: Leptagonia analoga (Phillips), Rugosochonetes extensus (Chao), Levitusia humerosa (Sowerby), Tomiproductus elegantulus (Tolmatchoff), Marginicinctus marginicinctus (Prout), Marginicinctus sp., Marginatia burlingtonensis (Hall), Marginatia sp., Echinoconchus punctatus (Sowerby), Echinaria sp., Pustula pustulosa (Phillips), Ovatia elongata Muir-Wood and Cooper, Fluctuaria cf. undata (Defrance), Striatifera striata (Fischer), Orthotetes cf. australis (Campbell), Schellwienella radialis (Phillips), Rhipidomella michelini (Léveillé), R. kusbassica Beznossova, Rhipidomella sp., Schizophoria resupinata (Martin), S. pinguis Demanet, S. woodi Bond, S. mayesensis Carter, Cleiothyridina fimbriata (Phillips), C. harkeri Carter, Martinia aff. glabra (Sowerby), Spirifer liangchowensis Chao, "S." mundulus Rowley, Grandispirifer mylkensis Yang,

Unispirifer striatoconvolutus (Dun and Benson), U. kozuboensis (Minato), Unispirifer sp., Imbrexia cf. incertus (Hall), Kitakamithyris hikoroitiensis Minato, Kitakamithyris sp., Syringothyris texta (Hall), Asyrinxia nipponotrigonalis (Minato), Asyrinxia sp., Pseudosyrinx jumonjiensis (Minato), Pseudosyrinx sp. and Dimegelasma sp.

In terms of biostratigraphy, the lower Carboniferous formations, except for the upper Visean Onimaru Formation, in the central part of the South Kitakami Belt were considered to be correlated with the lower Tournaisian to the lower Visean (Minato, 1941, 1951, 1952; Minato et al., 1953, 1979b; Minato and Kato, 1979) based mainly on the brachiopods, Leptagonia analoga, Spirifer kozuboensis (= Unispirifer kozuboensis), Imbrexia cf. incertus (= Imbrexia incertus), Kitakamithyris semicircularis (= K. hikoroitiensis), Syringothyris transversa (= S. texta), S. jumonjiensis (= Pseudosyrinx jumonjiensis) and Fusella nipponotrigonalis (= Asyrinxia nipponotrigonalis) and corals, Palaeosmilia membiensis, Amplexus nipponensis and Sugiyamaella carbonarium. After that, the middle part of the Arisu Formation was correlated with the lower Visean by the brachiopods, Marginatia burlingtonensis, Syringothyris transversa (= S. texta) and Unispirifer sp. (= U. minnewankensis) (Tazawa, 1985, 2006); and the Odaira Formation was correlated with the upper Visean by the corals, Pseudouralinia tangpakouensis, Siphonophyllia sp., Sugiyamaella sp., Caninophyllum? sp., Kueichouphyllum heishikuanensis, Yuanophyllum kansuense, "Lophophyllum" sp. and "Caninia" sp. (Kawamura et al., 1985) and brachiopods, Leptagonia analoga, Rugosochonetes extensus, Marginatia burlingtonensis, Echinoconchus punctatus, Echinaria sp., Pustula pustulosa, Schellwienella radialis, Cleiothyridina fimbriata, Spirifer liangchowensis, Kitakamithyris sp. and Pseudosyrinx sp. (Tazawa et al., 1981; Tazawa, 1981b). Recently, the Shittakazawa Formation was correlated with the upper Tournaisian by four brachiopod species, Rhipidomella kusbassica, Schizophoria pinguis, S. mayesensis and Unispirifer kozuboensis (Tazawa and Kurita, 2019a); the Arisu Formation with the lower Visean by brachiopods (17 species in 13 genera), Levitusia humerosa, Tomiproductus elegantulus, Marginatia burlingtonensis, Ovatia elongata, Rhipidomella michelini, Schizophoria resupinata, S. pinguis, S. woodi, Cleiothyridina harkeri, Grandispirifer mylkensis, Unispirifer striatoconvolutus, Unispirifer sp., Kitakamithyris hikoroitiensis, Syringothyris texta, S. platypleura, Asyrinxia nipponotrigonaris and Pseudosyrinx jumonjiensis (Tazawa and Ibaraki, 2019; Tazawa and Iryu, 2019; Tazawa and Kurita, 2019b); and the uppermost part of the Odaira Formation with the upper Visean by brachiopods (11 species in 11 genera), Leptagonia analoga, Rugosochonetes extensus, Marginatia burlingtonensis, Echinoconchs punctatus, Echinaria sp., Pustula pustulosa, Schellwienella radialis, Cleiothyridina fimbriata, Spirifer liangchowensis, Kitakamithyris sp. and Pseudosyrinx sp. (Tazawa, 2017).

In palaeobiogeography, Minato (1956) explained in short that the early Carboiferous marine fauna of the South Kitakami Belt has a close affinity with those of eastern Australia and the Mongolian geosynclinal region (central Asia), and quite different from those of southern China. Recently, Tazawa and his collaboraters (Tazawa, 2017; Tazawa and Iryu, 2019; Tazawa and Kurita, 2019b) proposed that early and late Visean brachiopod faunas of the central part of the South Kitakami Belt resemble those of western Europe and central Asia (Kazakhstan, Uzbekistan, Kyrgyzstan and northwestern China), and the South Kitakami region probably belonged to the North China Province of Yang (1983) and was located near and to the east of the North China Block during the Visean.

#### **STRATIGRAPHY**

The lower Carboniferous succession of the central part (Shimoarisu, Yokota, Yahagi, Nisawa, Okuhinotsuchi amd Shizu areas; Figs. 5-9) of the South Kitakami Belt is divided into four formations: the Shittakazawa, Arisu, Odaira and Onimaru Formations in stratigraphic ascending order. Furthermore, each formation, except for the Onimaru Formation, is subdivided into three units in stratigraphic ascending order: the Shittakazawa Formation is subdivided into the ST1, ST2 and ST3 units; the Arisu Formation into the AR1, AR2 and AR3 units; and the Odaira Formation into the OD1, OD2 and OD3 units (Figs. 10-13). In this paper, the upper Visean volcaniclastic sequence in the Nisawa, Okuhinotsuchi and Shizu areas is assigned to the Odaira Formation (named by Onuki, 1956; defined by Minato et al., 1979b), rather than the Karoyama Formation (Tazawa et al., 1981) or the middle and upper parts of the Karosawa Formation (Kawamura, 1985c).

#### Shittakazawa Formation

The stratigraphy of the Shittakazawa Formation was studied by Kawamura (1985a) and Tazawa and Iryu (2019) in the Shimoarisu area and by Tazawa and Kurita (1986, 2019a) in the Okuhinotsuchi area (Fig. 5). According to Tazawa and Kurita (2019a), the Shittakazawa Formation in the Okuhinotuchi area has a total thickness of 986 m and is subdivided into a lower part (ST1 Unit: alternating light grey to light greenish-grey rhyolitic tuff and conglomerate, with thin layers of limestone and green to dark green andesitic tuff, 257 m thick), a middle part (ST2 Unit: rhyolitic tuff, 500 m thick) and an upper part (ST3 Unit: alternating rhyolitic tuff, sandstone and shale, with a thin limestone layer, 229 m thick; Fig. 13). Brachiopod fossils were collected from one locality (KAR1), an outcrop of light grey rhyolitic tuffaceous shale of the ST3 Unit.

#### **Arisu Formation**

Stratigraphy of the Arisu Formation was studied by Kawamura (1985a) and Tazawa and Iryu (2019) in the Shimoarisu area and by Tazawa and Katayama (1979), Tazawa (1979), Kawamura (1985b) and Tazawa and Ibaraki (2019) in the Yokota area (Fig. 6). According to Tazawa and Ibaraki

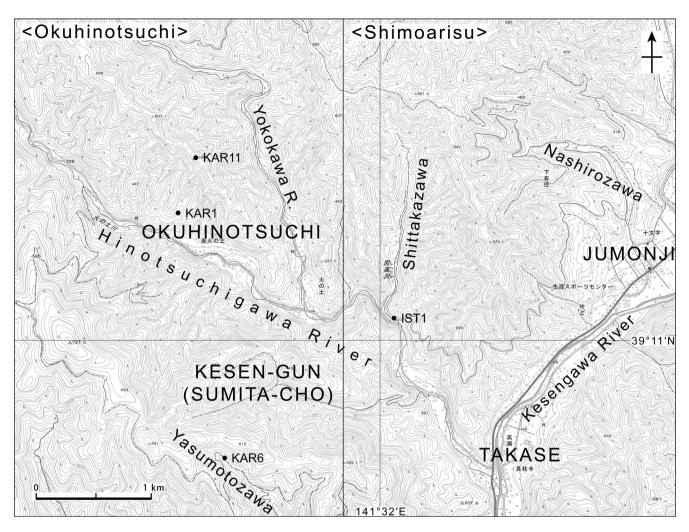


FIGURE 5. Map showing the fossil localities KAR1, KAR6 and KAR11 in the Okuhinotuchi area, and IST1 in the Shimoarisu area (using the electronic topographical map of GSI).

(2019), the Arisu Formation in the Yokota area has a total thickness of 330 m and is subdivided into a lower part (AR1 Unit: green to dark green andesitic lapilli tuff, 40 m thick), a middle part (AR2 Unit: sandstone with subordinate andesitic tuff and limestone, 260 m thick) and an upper part (AR3 Unit: black shale with a thin limestone bed as the topmost bed, 130 m thick; Fig. 11). Brachiopod fossils occur from the AR2 and AR3 units, although the AR1 Unit is barren of fossils.

#### **Odaira Formation**

Stratigraphy of the Odaira Formation was studied by Kawamura (1985a) and Tazawa and Iryu (2019) in the Shimoarisu area, by Tazawa and Katayama (1979), Tazawa (1979, 2017), Kawamura (1985b) and Kawamura et al. (1985) in the Yokota area, by Tazawa et al. (1981) and Kawamura (1985c) in the Nisawa area (Fig. 8), and by Kawamura (1985c)

and Tazawa and Kurita (2019a) in the Shizu area (Fig. 9). According to Tazawa and Katayama (1979) and Tazawa (1979, 2017), the Odaira Formation in the Yokota area has a total thickness of about 550 m and is subdivided into a lower part (OD1 Unit: andesitic tuff and tuff breccia, 125 m thick), a middle part (OD2 Unit: alternating sandstone–tuff, intercalated with thin limestone layers, 318 m thick) and an upper part (OD3 Unit: black shale and sandy limestone, 107 m thick; Fig. 11). Brachiopod fossils occur from the OD2 and OD3 units, although the OD1 Unit is barren of fossils.

#### MATERIALS

Most of the brachiopod specimens described herein, except for the specimens numbered UHR prefix, were collected from 42 localities (stations) in the Shimoarisu, Yokota, Yahagi, Nisawa, Okuhinotsuchi and Shizu areas of the South Kitakami

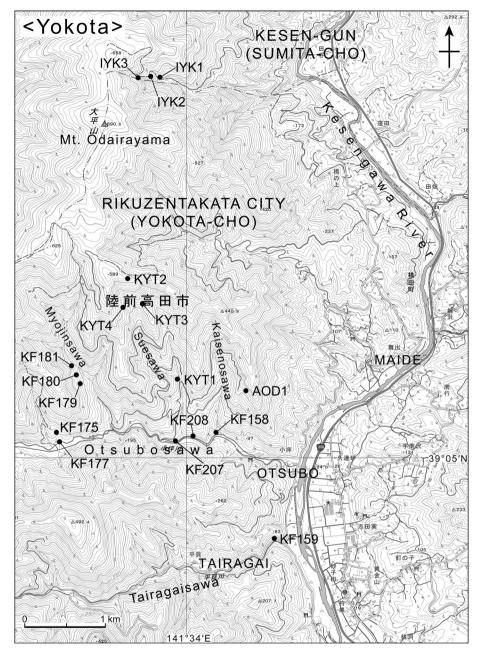


FIGURE 6. Map showing the fossil localities AOD1, IYK1, IYK2, IYK3, KF158, KF159, KF175, KF177, KF179, KF180, KF181, KF207, KF208, KYT1, KYT2, KYT3 and KYT4 in the Yokota area (using the electronic topographical map of GSI).

Belt. The topographic and stratigraphic locations, lithologies and brachiopod species of the 42 fossil localities are indicated in Figs. 5–13, and summarized in Fig. 14 and Appendix. The materials were collected by T. Katayama, F. Itabashi, Y. Iryu, M. Yamazaki, Y. Kurita, Y. Ibaraki, H. Araki and the present author. In addition, some specimens were prepared from the collections of the Hokkaido University Museum, Sapporo. The specimens described herein are registered and stored in the Department of Geology, Niigata University, Niigata (NU-B

prefix), the Tohoku University Museum, Sendai (IGPS prefix), the Hokkaido Univerity Museum, Sapporo (UHR prefix) and the Kesennuma Board of Education, Kesennuma (KCG prefix).

### BRACHIOPOD FAUNAS

The brachiopods described herein are the following 56 species in 39 genera, including a new species (*Levitusia elongata* sp. nov.): Orbiculoidea sp. Leptagonia analoga

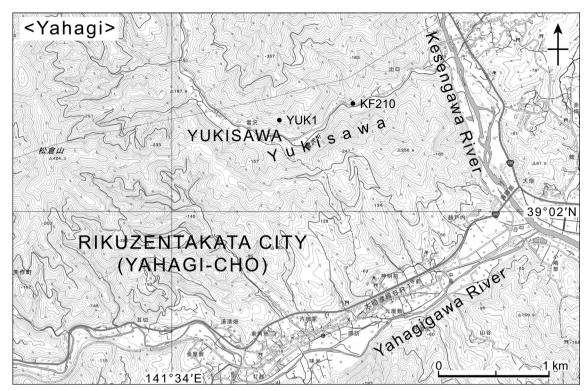


FIGURE 7. Map showing the fossil localities KF210 and YUK1 in the Yahagi area (using the electronic topographical map of GSI).

(Phillips, 1836), Rugosochonetes extensus (Chao, 1928), Rugosochonetes sp., Plicatifera plicatilis (Sowerby, 1824), P. pseudoplicatilis (Muir-Wood, 1928), Absenticosta uldzejtuensis Suursuren and Lazarev in Lazarev, 1991, Argentiproductus sp., Alitaria konincki (Muir-Wood and Cooper, 1960), Levitusia humerosa (Sowerby, 1822), L. elongata sp. nov., Tolmatchoffia robusta (Tolmatchoff, 1924), Tomiproductus elegantulus (Tolmatchoff, 1924), Marginicinctus marginicinctus (Prout, 1857), Marginatia burlingtonensis (Hall, 1858), Echinoconchus punctatus (Sowerby, 1822), Echinaria sp., Pustula pustulosa (Phillips, 1836), Ovatia elongata Muir-Wood and Cooper, 1960, Fluctuaria undata (Defrance, 1826), Striatifera angusta (Yanishevsky, 1910), Orthotetes keokuk (Hall, 1858), Schellwienella radialis (Phillips, 1836), Rhipidomella michelini (Léveillé, 1835), R. kusbassica Beznossova in Sarytcheva et al., 1963, Schizophoria resupinata (Martin, 1809), S. pinguis Demanet, 1934, S. woodi Bond, 1941, S. mayesensis Carter, 1999, Rotaia hikoroichiensis Tazawa, 2006, Cleiothyridina fimbriata (Phillips, 1836), C. harkeri Carter, 1987, Martinia georgei Tazawa in Tazawa et al., 2019, Spirifer liangchowensis Chao, 1929, Grandispirifer mylkensis Yang, 1959, Unispirifer striatoconvolutus (Dun and Benson in Benson et al., 1920), U. minnewankensis (Shimer, 1926), U. kozuboensis (Minato, 1952), Unispirifer sp., Brachythyrina sp., Imbrexia forbesi (Norwood and Pratten, 1855), I. incertus (Hall, 1858), Acuminothyris triangularis Roberts, 1963, Brachythyris chouteauensis (Weller, 1909), Kitakamithyris hikoroitiensis

Minato, 1951, Kitakamithyris sp., Torynifer asiatica Beznossova in Beznossova et al., 1962, Syringothyris texta (Hall, 1857), S. platypleura Weller, 1914, Syringothyris sp., Asyrinxia nipponotrigonalis (Minato, 1951), Asyrinxia sp., Pseudosyrinx jumonjiensis (Minato, 1951), Pseudosyrinx sp., Dimegelasma sp. and Punctospirifer sp.

The brachiopod species from the Shittakazawa, Arisu and Odaira Formations are classified into three faunas: the Shittakazawa fauna from the Shittakazawa Formation, the Arisu fauna from the Arisu Formatin, and the Odaira fauna from the Odaira Formation. Moreover, the three faunas are subdivided into five asemblages: the ST3 assemblage from the ST3 Unit (upper part of the Shittakazawa Formation), the AR2 assemblage from the AR2 Unit (middle part of the Arisu Formation), the AR3 assemblage from the AR3 Unit (upper part of the Arisu Formation), the OD2 assemblage from the OD2 Unit (middle part of the Odaira Formation), and the OD3 assemblage from the OD3 Unit (upper part of the Odaira Formation).

#### Shittakazawa Fauna

# ST3 assemblage

The ST3 assemblage, from the ST3 Unit of the Shittakazawa Formation, includes four species in three genera: *Rhipidomella kusbassica*, *Schizophoria pinguis*, *S. mayesensis* and *Unispirifer kozuboensis*. Of these species, *Schizophoria mayesensis* is

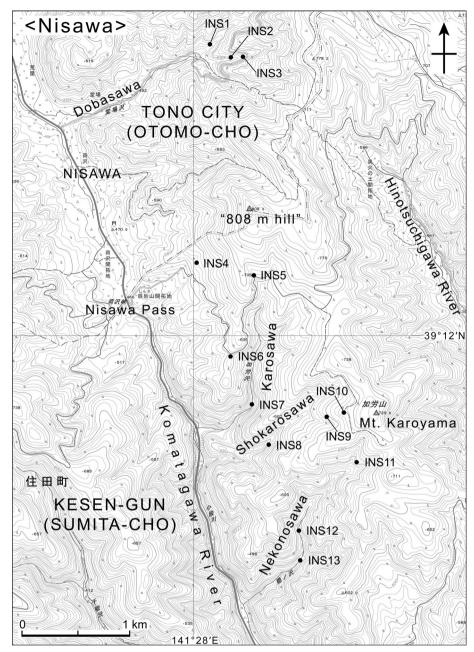


FIGURE 8. Map showing the fossil localities INS1, INS2, INS3, INS4, INS5, INS6, INS7, INS8, INS9, INS10, INS11, INS12 and INS13 in the Nisawa area (using the electronic topographical map of GSI).

common; and the other species are rare (Fig. 14).

#### Arisu Fauna

# AR2 assemblage

The AR2 assemblage, from the AR2 Unit of the Arisu Formation, includes 22 species in 17 genera: Levitusia humerosa, Tolmatchoffia robusta, Tomiproductus elegantulus, Marginatia burlingtonensis, Ovatia elongata, Orthotetes keokuk, Rhipidomella michelini, Schizophoria resupinata, S. pinguis, S.

woodi, Cleiothyridina harkeri, Grandispirifer mylkensis, Unispirifer striatoconvolutus, U. kozuboensis, Unispirifer sp., Acuminothyris triangularis, Brachythyris chouteauensis, Kitakamithyris hikoroitiensis, Syringothyris texta, S. platypleura, Asyrinxia nipponotrigonalis and Pseudosyrinx jumonjiensis. Of these species, Schizophoria resupinata is abundant; Tolmatchoffia robusta, Marginatia burlingtonensis, Rhipidomella michelini, Schizophoria pinguis, Unispirifer striatoconvolutus, U. kozuboensis and Kitakamithyris hikoroitiensis are common; and the other species are rare (Fig. 14).

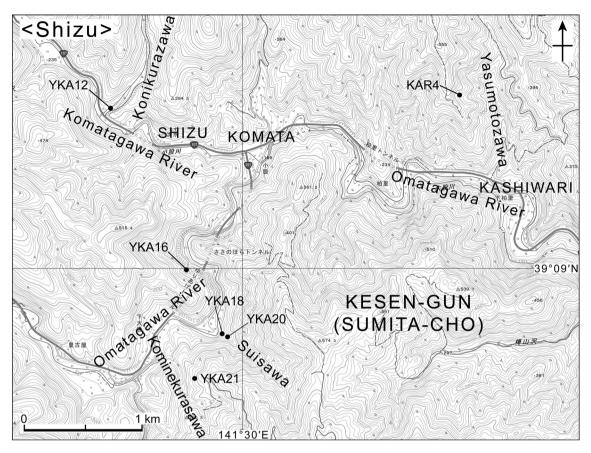


FIGURE 9. Map showing the fossil localities KAR4, YKA12, YKA16, YKA18, YKA20 and YKA21 in the Shizu area (using the electronic topographical map of GSI).

# AR3 assemblage

The AR3 assemblage, from the AR3 Unit of the Arisu Formation, includes five species in five genera: *Orbiculoidea* sp., *Marginatia burlingtonensis*, *Unispirifer minnewankensis*, *Brachythyrina* sp. and *Punctospirifer* sp. All the species are rare (Fig. 14).

# Odaira Fauna

# OD2 assemblage

The OD2 assemblage, from the OD2 Unit of the Odaira Formation, includes 17 species in 16 genera, with a new species (Levitusia elongata sp. nov.): Absenticosta uldzejtuensis, Levitusia elongata sp. nov., Marginicinctus marginicinctus, Fluctuaria undata, Striatifera angusta, Orthotetes keokuk, Rhipidomella michelini, Schizophoria resupinata, Rotaia hikoroichiensis, Martinia georgei, Spirifer liangchowensis, Imbrexia incertus, Brachythyris chouteauensis, Syringothyris sp., Asyrinxia nipponotrigonalis, Asyrinxia sp. and Dimegelasma sp. Of these species, Rhipidomella michelini and Schizophoria resupinata are abundant; Absenticosta uldzejtuensis, Martinia georgei, Spirifer liangchowensis,

Syringothyris sp. and Dimegelasma sp. are common; and the other species are rare (Fig. 14).

#### OD3 assemblage

The OD3 assemblage, from the OD3 Unit of the Odaira Formation, includes 25 species in 22 genera: Leptagonia analoga, Rugosochonetes extensus, Rugosochonetes sp., Plicatifera plicatilis, P. pseudoplicatilis, Argentiproductus sp., Alitaria konincki, Marginicinctus marginicinctus, Marginatia burlingtonensis, Echinoconchus punctatus, Echinaria sp., Pustula pustulosa, Fluctuaria undata, Orthotetes keokuk, Schellwienella radialis, Rhipidomella michelini, Cleiothyridina fimbriata, Martinia georgei, Spirifer liangchowensis, Imbrexia forbesi, I. incertus, Brachythyris chouteauensis, Kitakamithyris sp., Torynifer asiatica and Pseudosyrinx sp. Of these species, Spirifer liangchowensis is abundant; Alitaria konincki, Marginatia burlingtonensis, Imbrexia forbesi and I. incertus are common; and the other species are rare (Fig. 14).

#### AGE AND CORRELATION

# Shittakazawa Fauna

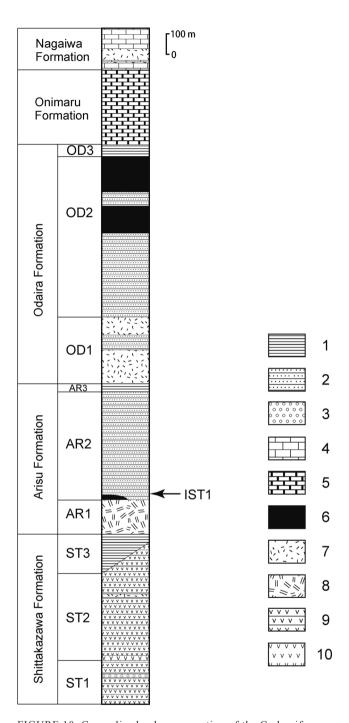


FIGURE 10. Generalized columnar section of the Carboniferous formations in the Shimoarisu area, showing the fossil horizon IST1 in the AR2 Unit of the Arisu Formation (modified from Tazawa and Iryu, 2019). 1, shale; 2, alternating shale and sandstone; 3, conglomerate; 4, limestone of the Nagaiwa Formation; 5, 6, limestone of the Arisu and Odaira Formations; 7, andesitic tuff; 8, andesitic lapilli tuff; 9, alternating shale and rhyolitic tuff; 10, rhyolitic tuff.

#### ST3 assemblage

The stratigraphic distributions of the brachiopod species of the ST3 assemblage are described in the section "Systematic descriptions", and summarized in Fig. 15. Of the brachiopods listed above, *Rhipidomella kusbassica* is known from the lower Tournaisian–lower Visean, *Schizophoria pinguis* is known from the upper Tournaisian–upper Visean, *Schizophoria mayesensis* occurs in the upper Tournaisian, and *Unispirifer kozuboensis* occurs in the upper Tournaisian–lower Visean. In summary, the ST3 assemblage is identified as late Tournaisian in age. Thus, the upper part (ST3 Unit) of the Shittakazawa Formation is correlated with the upper Tournaisian. This conclusion is consistent with the finding of Tazawa and Kurita (2019a).

#### Arisu Fauna

#### AR2 assemblage

The stratigraphic distributions of the brachiopod species of the AR2 assemblage are described in the section "Systematic descriptions", and summarized in Fig. 16. Of the brachiopods listed above, Levitusia humerosa, Syringothyris texta and Pseudosyrinx jumonjiensis are known only from the lower Visean, Tolmatchoffia robusta, Kitakamithyris hikoroitiensis and Syringothyris platypleura have a stratigraphic range of the lower Tournaisian - lower Visean, and four species (Cleiothyridina harkeri, Grandispirifer mylkensis, Unispirifer kozuboensis and Acuminothyris triangularis) are known from the upper Tournaisian-lower Visean. In contrast, Asyrinxia nipponotrigonalis occurs in the lower and upper Visean, three species (Tomiproductus elegantulus, Ovatia elongata and Brachythyris chouteauensis) are known from the lower Tournaisian-upper Visean, and five species (Marginatia burlingtonensis, Orthotetes keokuk, Schizophoria resupinata, S. pinguis and Unispirifer striatoconvolutus) have a stratigraphic range of the upper Tournaisian-upper Visean. Two species (Rhipidomella michelini and Schizophoria woodi) are long-ranging species, from the upper Tournaisian to the Serpukhovian. To summarize, the age of the AR2 assemblage is identified as early Visean; thus, the middle part (AR2 Unit) of the Arisu Formation is correlated with the lower Visean. This conclusion is consistent with the age determination and correlation by Tazawa and Ibaraki (2019), Tazawa and Iryu (2019) and Tazawa and Kurita (2019b).

#### AR3 assemblage

The stratigraphic distributins of the brachiopod species of the AR3 assemblage are described in the section "Systematic descriptions", and summarized in Fig. 17. Of the brachiopods listed above, *Marginatia burlingtonensis* is known from the upper Tournaisian–upper Visean, and *Unispirifer minnewankensis* is known from the upper Tournaisian–lower Visean. The other species (*Orbiculoidea* sp., *Brachythyrina* sp. and *Punctospirifer* sp.) are obscure in age, because of their indeterminate state at species level. In summary, the age of the AR3 assemblage is identified as early Visean, not to be late Tournaisian–early Visean, because this assemblage is stratigraphically younger

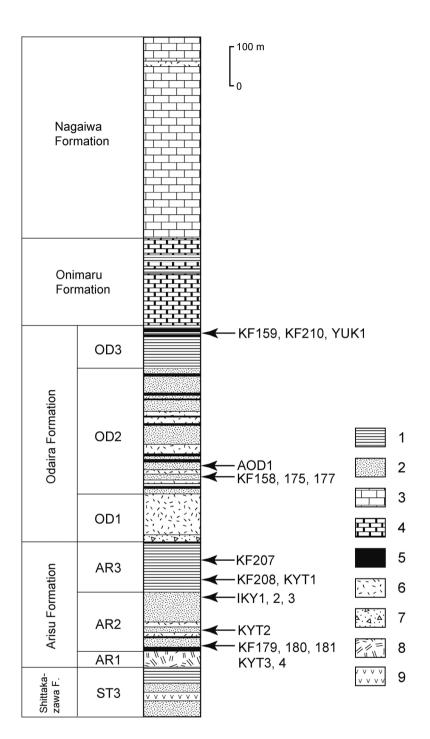


FIGURE 11. Generalized columnar section of the Carboniferous formations in the Yokota—Yahagi area, showing the fossil horizons in the AR2 and AR3 units in the Arisu Formation and the OD2 and OD3 units in the Odaira Formation (modified and adapted from Tazawa, 2017). 1, shale; 2, sandstone; 3, limestone of the Nagaiwa Formation; 4, limestone of the Onimaru Formation; 5, limestone of the Arisu and Odaira Formations; 6, andesitic tuff; 7, andesitic tuff breccia; 8, andesitic lapilli tuff; 9, rhyolitic tuff.

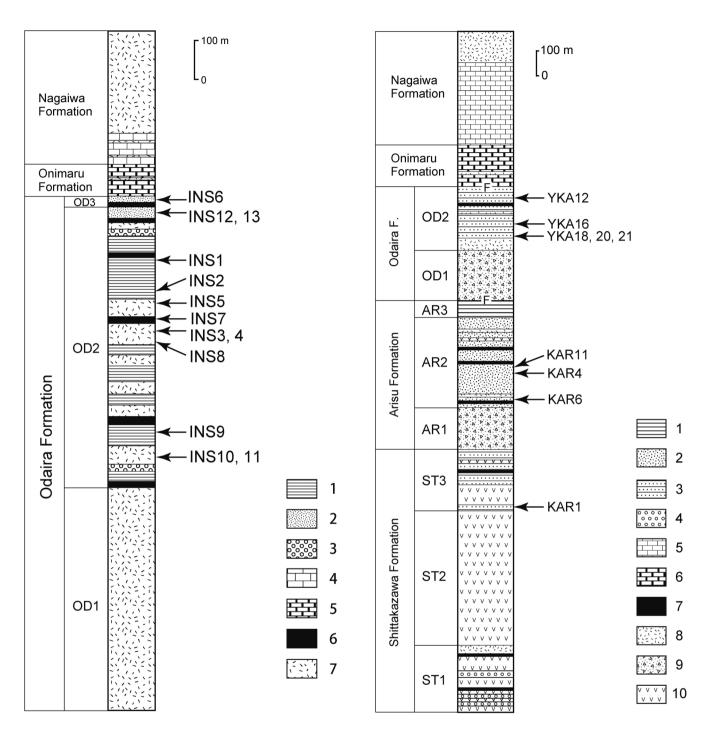


FIGURE 12. Generalized columnar section of the Carboniferous formations in the Nisawa area, showing the fossil horizons in the OD2 and OD3 units in the Odaira Formation (modified and adapted from Tazawa et al., 1981). 1, shale; 2, sandstone; 3, conglomerate; 4, limestone of the Nagaiwa Formation; 5, limestone of the Onimaru Formation; 6, limestone of the Odaira Formation; 7, andesitic tuff.

FIGURE 13. Generalized columnar section of the Carboniferous formations in the Okuhinotsuchi–Shizu area, showing the fossil horizons in the ST3 Unit in the Shittakazawa Formation, the AR2 Unit in the Arisu Formation, and the OD2 Unit in the Odaira Formation (modified and adapted from Tazawa and Kurita, 2019a). 1, shale; 2, sandstone; 3, alternating shale and sandstone; 4, conglomerate; 5, limestone of the Nagaiwa Formation; 6, limestone of the Onimaru Formation; 7, limestone of the Shittakazawa, Arisu and Odaira Formations; 8, andesitic tuff; 9, andesitic lapilli tuff; 10, rhyolitic tuff. F = fault.

Formations, units and localities Shittakazawa Formation	/ Okubine	-tsuchi		Shizu	Shimoarisu		Ar	isu	Fo		Yok											Nis	saw	a		0	dai	ra I	Forn		nizu tior			Y	'oko	ota		Voleta	Y OKOTA	Yahagi
Species ST3 Unit —	KAR1	KAR6	KAR11	KAR4	IST1	Т	П	Ť	KYT3		KYT2	IYKI	17 KZ	IYKS	Т	KYII	╅	OSIO	IISII	650	INS3	NS4	NS7	INS5		INSI	Ť	Ť,	VKA20	0704	YKAZI	MAIO	YKAIZ	r 130	KF175	KF177	_†	OD OZNI	$\neg$	Uni VIIIV
Orbiculoidea sp.	ŀ	¥	<u>~</u> ,	-	Ĭ	× ,	*	×	×	¥	ž	- 1	1	7	× )	_	z j	7	7	7 -	1=	+	_	F	=	-	7	7	7	+		7	7 -	-	<u> </u>	<u>*</u>	<b>₹ </b> }	1	-	7
Leptagonia analoga	Н	H	$^{\dagger}$	$\forall$	┪	$\dashv$	$\dashv$	$\dashv$	$\dashv$	Н	H	+	+	+	+	Ť	+	$^{+}$	+	$^{+}$	$^{+}$	t	t	Н	$\vdash$	$\dashv$	$\dashv$	$^{\dagger}$	+	$^{+}$	$^{\dagger}$	+	$^{+}$	†	$^{+}$	+	+	1	R	$^{+}$
Rugosochonetes extensus		П	T	T								$\top$	T	1	T	T	T	T	$\top$	T	T	T		П					T	T	T	T	T	T	T	T	T	1	R	]
Rugosochonetes sp.		П		$\Box$	$\Box$								$\perp$	I	$\Box$		I		$\Box$		I								$\perp$	I		$\Box$	I			$\Box$	I	$\perp$	I	]
Plicatifera plicatilis	Ц	Ц	4	4	4	_	_	_	4		Ц	_	4	4	4	4	4	4	4	4	1	╀		Ш		Ц	4	4	$\perp$	1	4	4	4	4	4	4	4	4	4	]
Plicatifera pseudoplicatilis	Н	Н	_	4	4	4	4	4	4		Ц	_	4	4	4	4	4	4	4	4	_	╀	_	Ш	Н	$\dashv$	4	4	4	1	4	4	+	4	4	4	1	+	+	]
Absenticosta uldzejtuensis	Н	Н	+	+	$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\dashv$		Н	+	+	+	+	+	+	+	+	+	+	╀	+	Н	-	$\dashv$	$\dashv$	+	10	7	+	+	+	+	+	+	R	+	+	4
Argentiproductus sp. Alitaria koninchi	Н	Н	+	+	$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\dashv$		Н	+	+	+	+	+	+	+	+	+	+	╁	$\vdash$	Н	-	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	+	]
Levitusia humerosa	Н	Н	R	+	$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\dashv$	Н	Н	+	+	╅	+	+	╅	+	+	+	+	+	$\vdash$	Н	$\dashv$	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	+	+
Levitusia elongata sp. nov.	H	H		$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\dashv$	H	H	+	+	+	+	+	+	$^{+}$	R	+	+	t	R	H	$\forall$	$\dashv$	$\dashv$	$\top$	+	†	R	$^{\dagger}$	R	+	+	+	+	+	+	+
Tolmatchoffia robusta	H	H	$\top$	$\dashv$	┪	С	$\dashv$	R	$\dashv$	П	H	$\top$	$\top$	十	$\top$	$\top$	$\top$	$\top$	$\top$	$\dagger$	T	T	+	П	Н	H	$\dashv$	$\top$	$\dagger$	Ť	$\top$	$\dagger$	$\top$	†	$\top$	$\top$	T	$\dagger$	$\top$	$\dagger$
Tomiproductus elegantulus			╛			$\overline{}$		R	J			R ]	R	J	Ī	╛	丁	Ī	J	1		Ι	L	П			丁	╛		Ţ	J	J	╧	J	╛	Ī	J			I
Marginicinctus marginicinctus	П	П	Ţ	Ţ	⅃	I	⅃	$\Box$	$\Box$		П	Ţ	Ţ	Ţ	Ţ	Ţ	Ţ	Ţ	Ţ	Ţ	R	L					J	R	Ţ	I	Ţ	Ţ	Ţ	Ţ	Ţ	Ţ	Ţ	T	-	R
Marginatia burlingtonensis	Ц	Ц	4	4	_	_	4	_	R		Ц	4	C I	R	R		R	4	4	$\perp$	$\perp$	┖		Ш		Ц	4	4	$\perp$	1	4	4	$\perp$	4	4	4	4	_	C	_
Echinoconchus pnctatus	Н	Н	$\dashv$	4	4	$\dashv$	4	4	_	Ц	Ц	+	4	4	+	4	4	4	4	+	+	$\perp$	1	Н	Ц	Ц	4	+	+	4	+	4	+	4	4	$\perp$	4	_	R	4
Echinaria sp.	Н	Н	$\dashv$	+	$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\dashv$	Н	Н	+	+	4	+	+	4	+	+	+	+	╀	$\vdash$	Н	Н	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	_	R	+
Pustula pustulosa Ovatia elongata	Н	Н	+	+	<u> </u>	$\dashv$	$\dashv$	$\dashv$	$\dashv$		Н	+	+	+	+	+	+	+	+	+	+	╀	$\vdash$	Н	-	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	R	+
Fluctuaria undata	Н	Н	+	+	R	$\dashv$	$\dashv$	$\dashv$	$\dashv$	-	Н	+	+	+	+	+	+	+	+	+	+	+	╁	Н	R	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	+,	R
Striatifera angusta	Н	Н	$\dashv$	+	$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\dashv$	Н	Н	+	+	╁	+	+	╁	+	+	+	+	╁	+	Н	K	$\dashv$	R	+	+	+	+	+	+	+	+	+	+	+	+	+
Orthotetes keokuk	Н	Н	$\dashv$	+	$\dashv$	R	$\dashv$	R	$\dashv$	-	$\forall$	+	+	+	+	+	+	+	+	+	+	+	R	Н	$\vdash$	$\dashv$		+	+	╁	+	+	+	+	+	+	+	+	+	1
Schellwienella radialis	Н	H	$\dashv$	$\forall$	$\dashv$	$\stackrel{\sim}{+}$	$\dashv$		$\dashv$	Н	$\forall$	+	+	+	+	+	+	+	+	+	+	+	<u> ``</u>	Н	$\dashv$	$\dashv$	$\dashv$	$^{+}$	╁	╁	+	+	+	+	+	+	+	† <sub>1</sub>	R	ť
Rhipidomella michelini	Н	H	$\dashv$	$\forall$	C	С	R	R	$\dashv$		$\forall$	R	$^{\dagger}$	†	$\top$	$\top$	†	$\top$	$\top$	$^{+}$	+	t	T	Н	П	$\dashv$	$\dashv$	$\top$	+	$^{\dagger}$		R	1	4	R	$\top$	†	Ť	+	1
Rhipidomella kusbassica	R	П	╅	7		T	T	$\neg$	$\exists$		П	十	$^{\dagger}$	†	$\top$	7	†	7	$\top$	Ť	十	T	T	П	П	T	$\dashv$	T	$\top$	$^{\dagger}$	†	†	十	T	T	$\forall$	†	十	$^{\dagger}$	T
Schizophoria resupinata	П	П	╅	T	A	一	┪	ヿ	╗	П	П	一	$\top$	7	ヿ	T	Ţ	R	R I	R	$\top$	T	R	П	R	П	╛	R	R I	₹ .	Α.	A	I	4	1	c	7	$\top$	T	T
Schizophoria pinguis	R			I	C	C	R	R					I	I	$\Box$		I	I	I											T	T				1	$\Box$	I		T	
Schizophoria woodi			$\Box$	$\Box$	R	$\Box$	$\Box$	$\Box$				$\Box$	$\perp$	I	$\Box$	$\Box$	$\perp$	$\Box$	$\perp$	$\perp$	$\perp$	L		Ш			$\Box$	$\Box$	$\perp$	Ι	$\Box$	$\perp$	$\perp$		$\Box$	$\Box$	$\perp$	$\perp$	$\perp$	$oxed{oxed}$
Schizophoria mayesensis	C	Ц	$\perp$	4	$\Box$	_	$\perp$	$\Box$	$\Box$		Ц	$\perp$	4	4	$\perp$	$\perp$	4	$\perp$	$\perp$	$\perp$	$\perp$	L		Ш		$\Box$	$\perp$	$\perp$	$\perp$	1	$\perp$	4	$\perp$	1	$\perp$	$\perp$	4	$\perp$	$\perp$	$\perp$
Rotaia hikoroichiensis	Ц	Щ	_	4	4	_	4	_	4	Ц	Ц	_	4	4	4	4	4	4	4	4	_	╀	┖	Ш	Ц	Ц	4	4	I	<u>₹</u>	4	4	4	4	4	4	4	4	4	4
Cleiothyridina fimbriata	Ц	Н	$\dashv$	4	4	$\dashv$	4	4	4		Ц	4	_	4	4	4	4	4	4	+	+	╀	_	Ш		4	4	4	+	4	4	4	4	4	4	4	4	1	R	4
Cleiothyridina harkeri	Н	Н	_	4	$\dashv$	4	$\dashv$	$\dashv$	$\dashv$	Н	Н	- []	R	4	+	+	4	_	4	4.	+	1	Ļ		_		$\dashv$	_	+	+	+	+	1	+	+	4	4	$\perp$	+	+
Martinia georgei	Н	Н	$\dashv$	+	$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\dashv$	-	Н	+	+	+	+	+	4	R	+	+1	R R	R	K	С	R	R	$\dashv$	R	+	+		+	C		+	+	4	R	+	+
Spirifer liangchowensis Grandispirifer mylkensis	Н	R	+	R	$\dashv$	$\dashv$	$\dashv$	R	$\dashv$	-	$\vdash$	+	+	+	+	+	+	+	+	+	+	+	╁	Н	$\dashv$	$\dashv$	$\dashv$	+	+	+	С	+	+	C	+	+	+	- 1	4	+
Unispirifer striatoconvolutus	Н	<u> </u>	+	$\overline{}$	R	С	$\dashv$	<u></u>	$\dashv$	-	$\vdash$	+	+	╅	+	+	+	+	+	+	+	+	+	Н	$\dashv$	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	+	+
Unispirifer minnewankensis	Н	Н	+	+	-		$\dashv$	$\dashv$	$\dashv$	$\dashv$	$\forall$	+	+	+	+	R	+	+	+	+	+	+	+	Н	$\dashv$	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	+	+
Unispirifar kozuboensis	R	H	$\dashv$	$\dashv$	$\dashv$	R	$\dashv$	C	$\dashv$	Н	R	+	+	+	+	+	+	+	+	+	+	+	t	Н	$\dashv$	$\dashv$	$\dashv$	+	+	+	+	+	+	$\dagger$	+	+	+	+	+	+
Unispirifer sp.	Ħ	H	$\dashv$	$\dashv$	R		$\dashv$	_	$\dashv$	Н		$\top$	$\top$	†	$\top$	$\top$	$\dagger$	$\top$	$\top$	+	$^{\dagger}$	T	T	Н	$\forall$	$\dashv$	$\dashv$	$\top$	+	$\dagger$	$\top$	$\dagger$	+	$\dagger$	$\top$	$\top$	†	+	+	+
Brachythyrina sp.	П	П	_	╛		$\exists$				П	$\Box$	$\top$	_	1	╛	_	R	✝	$\top$	†	T	T	Τ	П		$\Box$		_	十	Ť	$\top$	_	$\dagger$	†	_	_	†	丁	$\dagger$	十
Imbrexia forbesi			$\Box$											J		I	J	$\Box$	ight floor		Ι	I						$\Box$		I		I	$\perp$	J	I	$\Box$	I			-
Imbrexia incertus			$\Box$	1		$\Box$	$\Box$					I	I	I	I	I	I	I	I	I	Γ	Г					$\Box$	I	I	I	I	1	I	1	I	I	I	I	I	1
Acuminothyris triangularis	Ц	Ц	$\perp$	$\perp$	$\Box$	$\perp$	R		R	R	Ц	$\bot$	$\perp$	1	$\perp$	$\perp$	1	$\perp$	$\perp$	1	Ţ	Ĺ	Ĺ	Ц			Ţ	$\perp$	$\perp$	Ţ	$\perp$	$\perp$	1	1	$\perp$	$\perp$	1	$\perp$	$\perp$	$\perp$
Brachythyris chouteauensis	Ц	Ц	$\downarrow$	4	_	_	_	_	_	Ц	Ц	_	4	4	4	4	4	4	$\perp$	$\perp$	$\perp$	$\perp$	$\perp$	Ц	Ц	Ц	4	$\perp$	$\perp$	1	$\downarrow$	4	4	4	4	4	4	$\perp$	$\perp$	]
Kitakamithyris hikoroitiensis	Н	Н	+	4	R	C	_	4	_	Ц	Щ	R	+	4	+	+	4	+	+	+	+	$\perp$	$\vdash$	Н	Н	Ц	$\dashv$	+	+	+	+	4	+	4	+	+	4	4	$\perp$	4
Kitakamithyris sp.	Н	Н	+	+	$\dashv$	+	$\dashv$	$\dashv$	$\dashv$	Н	dash	+	+	4	+	+	+	+	+	+	+	+	$\vdash$	Н	Н	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+1	R	<u>]</u>
Torynifer asiatica	Н	Н	+	+	ᆔ	+	$\dashv$	R	$\dashv$	$\dashv$	$\vdash \vdash$	+	+	+	+	+	+	+	+	+	+	+	+	Н	$\vdash$	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	+'	R
Syringothyris texta Syringothyris platypleura	Н	Н	+	$\overline{}$	R R	+	$\dashv$	K	$\dashv$	Н	$\vdash$	+	+	+	+	+	+	+	+	+	+	+	+	Н	$\vdash$	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	+	+
Syringothyris sp.	Н	Н	+	+	*	+	$\dashv$	$\dashv$	$\dashv$	Н	$\forall$	+	+	+	+	+	+	+	+	+	+	+	+	Н	$\dashv$	$\dashv$	$\dashv$	+	+	+	+	+	+	c	+	+	+	+	+	+
Asyrinxia nipponotrigonalis	H	H	+	+	$\dashv$	+	$\dashv$	$\dashv$	R	$\dashv$	$\forall$	+	+	R	+	+	+	+	+	+	+	+	t	Н	$\forall$	$\dashv$	$\dashv$	+	+	+	+	+	+	+	+	+	+	+	+	+
Asyrinxia sp.	Н	H	+	+	$\dashv$	+	$\dashv$	$\dashv$	-`	Н	$\forall$	+	+	+	+	+	+	+	+	+	R	1	t	Н	$\dashv$	$\dashv$	$\dashv$	+	+	+	+	+	+	$\dagger$	+	+	+	+	+	+
Pseudosyrinx jumonjiensis	H	H	$\dagger$	$\forall$	R	$\dashv$	$\dashv$	R	$\dashv$	$\dashv$	$\forall$	$\dagger$	+	†	+	+	+	$\top$	+	$\dagger$	+`	T	T	H	$\forall$	$\dashv$	$\dashv$	$^{\dagger}$	+	†	$\dagger$	$^{\dagger}$	+	$\dagger$	+	+	†	+	$\dagger$	+
Pseudosyrinx sp.	Н	H	$\top$	$\forall$		$\top$	寸	-	$\dashv$	П	Н	$\top$	$\top$	†	$\top$	$\top$	$\dagger$	$\top$	$\dagger$	$\dagger$	T	T	T	П	П	$\dashv$	7	$\top$	$\dagger$	$\dagger$	$\dagger$	$\dagger$	$\dagger$	$\dagger$	$\top$	$\top$	T	1	R	$^{\dagger}$
	П	П	$\dashv$	$\forall$	┪	1	┪	┪	┪	П	П	$\top$	$\top$	†	$\top$	$\top$	†	$\top$	$\top$	$\top$	$\top$	T	T	П	П	$\Box$	7	$\top$	$\top$	T	$\top$	$\top$	7	С	$\top$	$\top$	╅	+	$\dagger$	十
Dimegelasma sp.																																								

FIGURE 14. Occurrence of brachiopod species from the Shittakazawa, Arisu and Odaira Formations in the Shimoarisu, Yokota, Yahagi, Nisawa, Okuhinotsuchi and Shizu areas, South Kitakami Belt. A, abundant; C, common; R, rare.

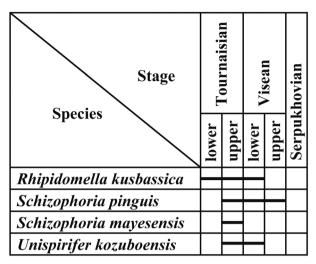


FIGURE 15. Stratigraphic distributions of brachiopod species of the ST3 assemblage (Shittakazawa fauna).

than the previously discussed AR2 assemblage (early Visean). Thus, the upper part (AR3 Unit) of the Arisu Formation is correlated with the lower Visean. This conclusion is consistent with the age determination and correlation by Tazawa (1985).

#### Odaira Fauna

# OD2 assemblage

The stratigraphic distributins of the brachiopod species of the OD2 assemblage are described in the section "Systematic descriptions", and summarized in Fig. 18. Of the brachiopods listed above, Absenticosta uldzejtuensis, Levitusia elongata sp. nov. and Marginicinctus marginicinctus are known only from the upper Visean, two species (Rotaia hikoroichiensis and Spirifer liangchowensis) are known from the lower-upper Visean, Brachythyris chowteauensis is known from the lower Tournaisian-upper Visean, and three species (Orthotetes keokuk, Schizophoria resupinata and Imbrexia incertus) are known from the upper Tournaisian-upper Visean. In contrast, Striatifera angusta is known from the upper Visean–Serpukhovian. Three species are long-ranging species: Rhipidomella michelini ranges from the upper Tournaisian to the Bashkirian, and both Fluctuaria undata and Martinia georgei range from the lower Visean to the Bashkirian. At the generic level, Syringothyris has a long range from the Famennian-Serpukhovian (Carter, 2006), Asyrinxia is known from the upper Tournaisian-upper Visean (Carter, 2006; Tazawa, 2018a), and Dimegelasma is known from the lower-upper Visean (Carter, 2006). In summary, the age of the OD2 assemblage is identified as late Visean. Thus, the middle part (OD2 Unit) of the Odaira Formation is correlated with the upper Visean.

#### OD3 assemblage

The stratigraphic distributins of the brachiopod species of the OD3 assemblage are described in the section "Systematic

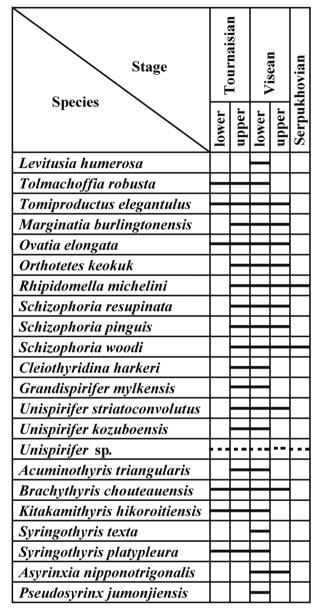


FIGURE 16. Stratigraphic distributions of brachiopod species of the AR2 assemblage in the Arisu fauna. Broken lines show those of genera.

descriptions", and summarized in Fig. 19. Of the brachiopods listed above, *Plicatifera plicatilis* and *Marginicinctus marginicinctus* are known only from the upper Visean, *Leptagonia analoga* and *Brachythyris chouteauensis* are known from the lower Tournaisian-upper Visean, five species (*Marginatia burlingtonensis*, *Orthotetes keokuk*, *Schellwienella radialis*, *Imbrexia forbesi* and *I. incertus*) are known from the upper Tournaisian-upper Visean, and four species (*Rugosochonetes extensus*, *Plicatifera pseudoplicatilis*, *Cleiothydina fimbriata* and *Spirifer liangchowensis*) are known from the lower-upper Visean. In contrast, *Alitaria konincki* and *Pustula pustulosa* are known from the lower

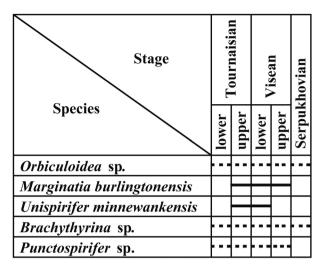


FIGURE 17. Stratigraphic distributions of brachiopod species of the AR3 assemblage in the Arisu fauna. Broken lines show those of genera.

Visean–Serpukhovian, and Fluctuaria undata is known from the lower Visean-Bashkirian. Four species are long-ranging species: Torinifer asiatica ranges from the lower Tournaisian to the Serpukhovian, Rhipidomela michelini ranges from the upper Tournaisian-Bashkirian, Echinoconchus punctatus ranges from the upper Tournaisian to the Asselian, and Martinia georgei ranges from the lower Visean to the Bashkirian. At the generic level, Rugosochonetes has a long range from the Tournaisian-Gzhelian (Racheboeuf, 2000), Argentiproductus occurs in the lower-upper Visean (Brunton et al., 2000), Echinaria is known from the upper Visean-Cisuralian (Tazawa, 1981a; Brunton et al., 2000; this study), Kitakamithyris is known from the Famennian-upper Visean (Tazawa, 2017, 2018b), and *Pseudosyrinx* is known from the upper Tournaisian-upper Visean (Carter, 2006; this study). In summary, the age of the OD3 assemblage is identified as late Visean. Thus, the upper part (OD3 Unit) of the Odaira Formation is correlated with the upper Visean. This conclusion is consistent with the age determination and correlation by Tazawa (1985, 2017) and Kawamura et al. (1985).

#### PALAEOBIOGEOGRAPHY

# Late Tournaisian

The geographic distributions of the late Tournaisian brachiopod species of the ST3 assemblage are described in the section "Systematic descriptions", and summarized in Figs. 20 and 21. Among the four species of the ST3 assemblage, one species also occurs in the USA (Oklahoma), the UK (England), Poland, Belgium, central Russia (Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang). Thus, the ST3 assemblage has a close affinity with those of the USA (Oklahoma), the UK (England), Poland, Belgium, central Russia (Kuznetsk Basin),

Stage	TomanoT	I our maisian	Viscon	v iscali	Serpukhovian	rian
Species	lower	npper	lower	upper	Serpu	Bashkirian
Absenticosta uldzejtuensis						
Levitusia elongata sp. nov.						
Marginicinctus marginicinctus						
Fluctuaria undata						
Striatifera angusta						
Orthotetes keokuk						
Rhipidomella michelini						
Schizophoria resupinata						
Rotaia hikoroichiensis						
Martinia georgei						
Spirifer liangchowensis						
Imbrexia incertus						
Brachythyris chouteauensis						
Syringothyris sp.						
Asyrinxia sp.						
Dimegelasma sp.						

FIGURE 18. Stratigraphic distributions of brachiopod species of the OD2 assemblage in the Odaira fauna. Broken lines show those of genera.

Kazakhstan and northwestern China (Xinjiang). This conclusion is consistent with the late Tournaisian biogeography based on the brachiopod faunas of the South Kitakami Belt: the HK1 asseblage from the lower part (HK1 Unit) of the Hikoroichi Formation in the Hikoroichi area (Tazawa, 2018c); and the KU1 assemblage from the lower part (KU1 Unit) of the Karaumedate Formation in the Nagasaka area (Tazawa et al., 2019).

## **Early Visean**

The geographic distributions of the early Visean brachiopod species of the AR2 and AR3 assemblages are described in the section "Systematic descriptions", and summarized in Figs. 22 and 23. Of the 22 species of the two assemblages, six species also occur in Kazakhstan and northwestern China (Xinjiang); five species are found in the UK (England), Belgium and central Russia (southern Urals and Kuznetsk Basin); four species have been reported from the USA (Missouri), Canada (Alberta) and Poland; and three species also occur in northern Russia (Verkhoyansk Range and Pechora Basin), western Russia (Moscow Basin and Donetz Basin), Iran, Uzbekistan,

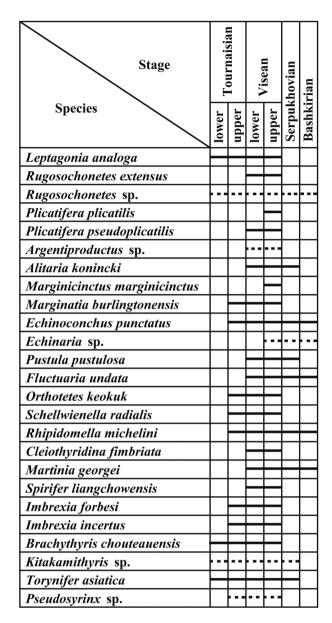


FIGURE 19. Stratigraphic distributions of brachiopod species of the OD3 assemblage in the Odaira fauna. Broken lines show those of genera.

Kyrgyzstan, northwestern China (Qinghai) and southwestern China (Yunnan). To summarize, the Arisu fauna (AR2 and AR3 assemblages) exhibits a close affinity with the early Carboniferous (Mississippian) brachiopod faunas of the UK (England), Belgium, central Russia (southern Urals and Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang), particularly with Kazakhstan and northwestern China (Xinjiang). This conclusion is consistent with the early Visean biogeography inferred from the brachiopod faunas of the South Kitakami Belt: the HK2 asseblage from the middle part (HK2 Unit) of the Hikoroichi Formation in the Hikoroichi area

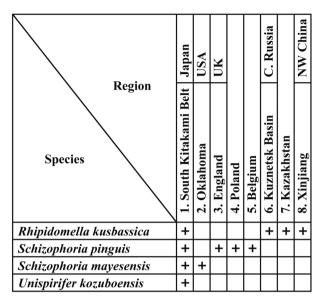


FIGURE 20. Geographic distributions of brachiopod species of the ST3 assemblage (Shittakazawa fauna).

(Tazawa, 2018c): and the Shimoarisu fauna from the middle part (AR2 Unit) of the Arisu Formation in the Shimoarisu area (Tazawa and Iryu, 2019).

# Late Visean

The geographic distributions of the late Visean brachiopod species of the OD2 and OD3 assemblages are described in the section "Systematic descriptions", and are summarized in Figs. 24 and 25. Among the 26 species of the two assemblages, 11 species also occur in Kazakhstan; 10 species also occur in the UK (England), Belgium, central Russia (southern Urals) and northwestern China (Xinjiang); seven species also occur in western Russia (Moscow Basin) and Kyrgyzstan; six species also occur in the UK (northern Ireland), central Russia (Kuznetsk Basin) and northwestern China (Gansu); five species also occur in the USA (Iowa), northern Russia (Verkhoyansk Range), Germany and Uzbekistan; and four species also occur in the USA (Missouri), northern Russia (Pechora Basin), the UK (Wales), Spain and western Russia (Donetz Basin). In summary, the Odaira fauna (OD2 and OD3 assemblages) exbits affinities with the early Carboniferous (Mississippian) brachiopod faunas of the UK (England), Belgium, central Russia (southern Urals), Kazakhstan and northwestern China (Xinjiang), particularly with Kazakhstan. This conclusion is consistent with the late Visean biogeography based on the brachiopod faunas of the South Kitakami Belt: the Tairagai fauna from the upper part of the Odaira Formation in the Yokota area (Tazawa, 2017); the HK4 asseblage from the upper part (HK4 Unit) of the Hikoroichi Formation in the Hikoroichi area (Tazawa, 2018c); and the KU4 assemblage from the upper part (KU4 Unit) of the Karaumedate Formation in the Nagasaka area (Tazawa et al., 2019).

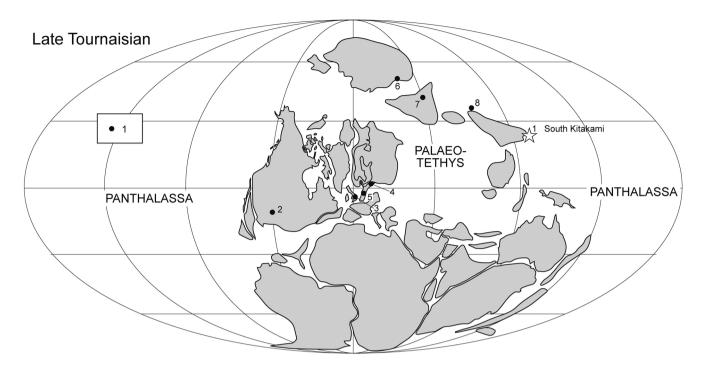


FIGURE 21. Late Tournaisian reconstruction map of the world (adapted from Qiao and Shen, 2014), showing the geographic distributions of brachiopod species of the ST3 assemblage (Shittakazawa fauna). Solid circles indicate numbers of brachiopod species listed in the ST3 assemblage. Station numbers are same as in Fig. 22.

# DISCUSSION: EARLY CARBONIFEROUS GEOGRAPHY AND BIOGEOGRAPHY OF THE SOUTH KITAKAMI BELT

Yang (1980, 1983, 1985) discussed the early Carboniferous brachiopod biogeography of China and the surrounding regions. He proposed the existence of three provinces: the North China Province, the South China Province and the Himalayan Province. The North China Province covers a broad area between the North China Block and the Siberian Block, including Kazakhstan (Altay Mountains), Kyrgyzstan (Tien Shan), northwestern China (Xinjiang), northern China (Inner Mongolia) and northeasten China (Heilongjiang). The fauna of the province is closely related to those of North America, Siberia and western Europe, and is characterized by Marginatia, Tolmatchoffia, Rotaia, Syringothyris, Pseudosyrinx, Grandispirifer and Balakhonia. The South China Province covers most areas of the South China Block, including the Yangtze River and Pearl River regions. The brachiopod fauna is peculiar to southern China and eastern Asia, and is characterized by Yanguania, Hunanoproductus, Eochoristites, Martiniella, Vitiliproductus, Datangia, Lochengia and Gondolina. The Himalayan Province covers the area south of the Yarlung Zangbo River, including Xizang (Tibet). The fauna is characterized by Fusella, Ovatia, Marginirugus, Syringothyris and Balakhonia. After that, Yang (1990) proposed three realms in the Early Carboniferous brachiopod biogeography in China and the adjacent regions, i.e., the Boreal Realm, the Tethyan Realm and the Himalayan Realm. He treated that northern Japan (South Kitakami) belonged to the Verkhoyansk–Northeast Japan Subprovince in the Boreal Realm.

The early Carboniferous brachiopod faunas of the central part of the South Kitakami Belt are characterized by Tolmatchoffia, Marginatia, Rhipidomella, Schizophoria, Rotaia, Grandispirifer, Unispirifer, Kitakamithyris, Syringothyris and Pseudosyrinx. The faunas display close affinities with those of North America, western Europe, northern, western and central Russia, Kazakhstan, Uzbekistan, Kyrgyzstan and norhwestern China, particularly with those of Kazakhstan and northwestern China. Thus, the early Carboniferous brachiopod faunas of the South Kitakami Belt are allied with those of the North China Province of Yang (1983). The South Kitakami region was probably the eastern extension of the province, and was located near and to the east of the North China Block during the early Carboniferous. This conclusion is consistent with the works of Tazawa (2002, 2006, 2017, 2018c), Tazawa and Iryu (2019), Tazawa and Kurita (2019b) and Tazawa et al. (2019). In the second contribution of the present series, Tazawa et al. (2019) proposed that the South Kitakami Belt was probably a shallow sea bordering a microcontinent, which consisted of the Hida-Oki Terrane (Suwa, 1990) and the East China Sea region, and was situated near and to the east of the North China Block at the eastern end of the Central Asian Orogenic Belt (CAOB)

		Japan						USA					Canada			N. Kussia			IIK IIK	1								W. Kussia				C. Kussia					_	NW China			N. China	NF China	NE CIIIIA	SW China	2	E. Australia
Region	1. South Kitakami Belt	2. Kanto Mountains	3. Akiyoshi Belt	4. Indiana	5. Illinois	6. Iowa	7. Missouri	8. Arkansas	9. Oklahoma	10. rexas	12. New Mexico	13. Arizona	14. Alberta	15. Verkhoyansk Range	16. Taimyr Peninsula	17. Novaya Zemlya	18. Pechora Basin	19. England	20. Wales	21. Isle of Man	22. Northern Ireland	23. Ireland	24. Poland	25. Germany	Z6. Belgium	27. France	29. Moscow Basin	30. Donetz Basin	31. Turkey	32. Iran	33. Western Urals	34. Southern Urais	35. Kuznetsk Basin	36. Kazakhstan	37. Uzbekistan	30 Vinijana	27. Allijang 40 Oinghoi	40. Çingilar	42. Ningxia	43. Shaanxi	44. Inner Mongolia	45. Jilin	46. Liaoning	47. Guizhou	48. Yunnan	49. New South Wales
Levitusia humerosa	+																	+						+	+			+			+	+	$\perp$		+ -	٢	$\perp$		$\perp$							
Tolmachoffia robusta	+								$\Box$		Γ	Т											T		Т	$\Box$	Т						+		<u> </u>	+ +	F	Τ	$\perp$						$\Box$	
Tomiproductus elegantulus	+																+													+	+		+	+					$\perp$							
Marginatia burlingtonensis	+		+		+	+		+					+																+		·	+	+	+		۲			L				+			
Ovatia elongata	+								+																											1	- ا	-	L							
Orthotetes keokuk	+					+	+				+	+		+																				+			Ι		$\perp$							
Rhipidomella michelini	+											Г			+		+	+	+		+	+	+	-	+ -	+ +	+ +	+		+	-	+		+ -	+	1	+ -	+ 4	+ +					+	+	
Schizophoria resupinata	+	+	+						Т	+	·I	Т	П	+	+	+	+	+	+			T.	+	Ţ.	+ -	+	+	+		+	·	+	+	+	+	1	F	Τ	$\Box$	+	+			+	+	$\Box$
Schizoporia pinguis	+																	+				<u> </u>	+	<u> </u>	+												Ι		$\perp$						$\Box$	
Schizophria woodi	+								Т		Γ	Т	Г					+		+	+	T.	+	Ţ.	+	Т	Т				·	+	Т	T		Т	Τ	Τ	Τ						$\Box$	П
Cleiothyridina harkeri	+							П	Т	Т	Т	Т	+	+	Г		П				П	Т	Т	Т	Т	Т	Т		П	П	Т	Т	Т	Т	Т	Т	Τ	Т	Т				П		Т	$\Box$
Grandispirifer mylkensis	+			П		Г	П	П	Т	Т	Т	Т	Т	Г	Г			П	П		Т	Т	Т	Т	Т	Т	Т		П	П	T	T	Т	T	Т	1	-	٠T	Т				П		Т	П
Unispirifer striatoconvolutus	+								Т	Т	Т		Т	Г							П	Т	Т		Т	Т	Т		П	П		T	Т	Т	Т		Τ	Т	Т				П		+	+
Unispirifer minnewankensis	+							П	T	Т	Т	Т	+	Г	Г			П	П	T	T	T	T	T	T	T	Т		П	T	T	T	T	T	T	1	F	Т	Т				П	П	Т	П
Unispirifer kozuboensis	+	$\neg$	П	П		Г	П	$\dashv$	$\top$	Τ	Τ	Τ	Τ	Γ	Γ	Γ	Г	Г	П	$\neg$	$\dashv$	$\top$	✝	T	$\top$	$\top$	Т	Т	П	$\dashv$	$\top$	$\top$	$\top$	$\top$	$\top$	T	Ť	Τ	Т	T	Г	Г	П	$\Box$	$\neg$	コ
Acuminothyris triangularis	+			П		Г	П	ヿ	十	$\top$	T	T	Τ	Г	Γ		Γ	Г	П	$\Box$	ヿ	す	T	T	$\top$	十	Τ	Γ	П	$\dashv$	T	T	T	T	$\top$	Ť	Ť	T	$\top$	Τ	Γ	Г	П		$\neg$	+
Brachythyris chouteauensis	+		П	П		Г	+	$\dashv$	+ -	+	T	T	+	Τ	Τ		Г	Г	П	$\Box$	ヿ	十	T	十	$\top$	十	1+		П	ヿ	す	1	+	+	十	Ť	Ť	T	$\top$	T	Г	+	П		$\neg$	ヿ
Kitakamithyris hikoroitiensis	+	$\neg$	П	П		Г	П	$\dashv$	十	$\top$	T	T	Τ	T	Τ	Г	Г	Г	$\sqcap$	$\neg$	$\dashv$	十	$\top$	T	$\top$	十	Τ	Т	П		$\top$	$\top$	$\top$	$\top$	十	Ť	$^{\dagger}$	Ť	$\top$	T	Г	Г	$\sqcap$		$\dashv$	ヿ
Syringothyris texta	+		П	+		Г	+	T	十	$\top$	T	T	Τ	T	Γ		Г	Г	П	T	ヿ	ナ	T	T	$\top$	十	Τ	Т	П	ヿ	$\top$	$\top$	7	$\top$	十	Ť	$\top$	T	$\top$	Т	Г	Г	П		$\neg$	╛
Syringothyris platypleura	+	П	П	П		Г	+	$\Box$	十	$\top$	T	T	Τ	Γ	Γ		Γ	Г	П	T	ヿ	す	T	T	$\top$	十	Τ	Γ	П	$\dashv$	十	T	T	T	$\top$	Ť	T	T	$\top$	T	Γ	Г	П		$\neg$	٦
Asyrinxia nipponotrigonalis	+	$\neg$	П	П		Г	П	$\dashv$	十	$\top$	T	T	Τ	Τ	Τ		Г	Г	$\sqcap$	$\exists$	$\dashv$	十	T	T	$\top$	十	Τ	Т	П	$\dashv$	十	T	$\top$	T	$\top$	Ť	Ť	T	$\top$	T	Г	Г	$\sqcap$	$\Box$	$\dashv$	٦
Pseudosyrinx jumonjiensis	+	$\neg$	П	П		Г	П	$\dashv$	十	$\top$	T	T	Τ	Т	Γ	Γ	Г	Г	П	$\neg$	寸	す	7	T	$\top$	十	Τ	Т	П	ヿ	$\top$	$\top$	$\top$	$\top$	十	Ť	$\top$	T	$\top$	T	Г	Г	П	$\Box$	$\dashv$	⊣

FIGURE 22. Geographic distributions of brachiopod species of the AR2 and AR3 assemblages in the Arisu fauna.

during the late Tournaisian and Visean. In the present paper, I consider that the microcontinent includes the Hida–Oki Terrane and the South Kitakami Terrane (Tazawa, 2004; revised by Tazawa, 2018d), but uncertain about the East China Sea region.

Minato (1956) briefly discussed the early Carboniferous (Hikoroichi–Arisu–Odaira ages, late Tournaisian–late Visean) biogeography and geography of the South Kitakami Belt based mainly on brachiopods. In that paper Minato proposed that the early Carboniferous brachiopod fauna of the South Kitakami Belt exhibited a close affinity with those of eastern Australia and the Mongolian geosynclinal region (central Asia), and was quite different from that of South China. Subsequently, Minato and Kato (1984) proposed that the early Carboniferous (Hikoroichi–Arisu–Odaira ages) faunas, consisting mainly of brachiopods and corals, of the South Kitakami Belt showed strong affinity with those of the United States, Russia and northern China.

Kobayashi and Hamada (1980) proposed two realms and five provinces in the Carboniferous trilobite biogeography, the Old World Realm (including the West-Central European, the European Russia-Central Asiatic, the Oriental and the Australian provinces) and the New World Province (including the North American Mid-Continent Province). They treated the South Kitakami fauna as a member of the Mongolian Geosynclinal Region in the European Russia-Central Asiatic

Province.

Qiao and Shen (2014) discussed the Misissippian global biogeography on the basis of quantitative analysis of the Mississipian brachiopod faunas of the world. It is noteworthy that South Kitakami was most closely related to northern Tianshan in Xinjiang, northwestern China (Qiao and Shen, 2014, fig. 6B) and located near and to the east of the North China Block (Qiao and Shen, 2014, figs. 3B) during the Visean.

In contrast to the above studies, Kawamura et al. (1999), Ehiro (2001), Okawa et al. (2013) and Isozaki et al. (2014, 2017) considered that South Kitakami was located near the South China Block during the Carboniferous. However, the palaeontological (taxonomical) data are insufficient or lacking in these studies. That hypothesis is not supported by the early Carboniferous brachiopod biogeography discussed above.

#### CONCLUSIONS

In this study, early Carboniferous brachiopods are described from the Shittakazawa, Arisu and Odaira Formations in the central part (Shimoarisu, Yokota, Yahagi, Nisawa, Okuhinotsuchi and Shizu areas) of the South Kitakami Belt, northeastern Japan. A total of 56 species in 29 genera are described, of which one (*Levitusia elongata* sp. nov.) is new. In terms of brachiopod biostratigraphy, the Shittakazawa

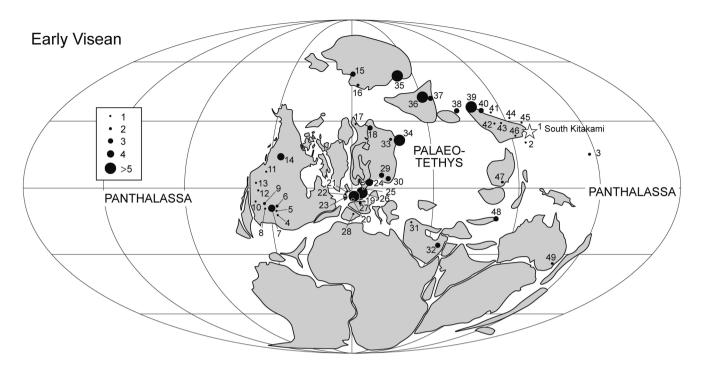


FIGURE 23. Early Visean reconstruction map of the world (adapted from Qiao and Shen, 2014), showing the geographic distributions of brachiopod species of the AR2 and AR3 assemblages in the Arisu fauna. Solid circles indicate numbers of brachiopod species listed in the AR2 and AR3 assemblages. Station numbers are same in Fig. 24.

		Japan						USA					Canada		N. Russia				711.	4								W. Russia					C. Russia						NW China				N. China		NE China		Ce China	CS CHINA		SW China	Australia	
Region	1. South Kitakami Belt	2. Hida Gaien Belt	3. Kanto Mountains	4. Akiyoshi Belt 5 Illinois	6. Iowa	7. Missouri	8. Arkansas	9. Oklahoma	10. rexas	12. Utah	13. New Mexico		15. Alberta 16. Verkhovansk Range		Novaya	19. Pechora Basin	20. Northern Urals	21. Scotland	22. England	24. Isle of Man	25. Northern Ireland	26. Ireland	27. Poland	28. Germany 29. Beloium	30. France	31. Spain	32. Algeria	33. Moscow Basin	35. Turkey	36. Iran	37. Afghanistan	Western	39. Southern Urals	41. Kuznetsk Basin	42. Kazakhstan	43. Uzbekistan	44. Kyrgyzstan	45. Xinjiang	46. Qinghai	47. Gansu	49. Mongolia	50. Inner Mongolia	51. Shanxi	52. Heilongjiang	53. Jilin	54. Liaoning	55 Huber	56. Guangdong 57. Guanoxi	57. Guangar 58. Guizhou	59. 3	W. 09	į
Leptagonia analoga	+	4	4	1	+ +	+	Ш	+	4	+	+	Ц	+ +	1	┸	+	Ц	4	+	+	+	Н		+ +	1	Ш		- +	+ +	+	Ц	4	+	+	+	Ц	Ц	+	-	+	1	╄	Ш	Ц	Н		+ +	+ +	۰	+	+ .	+
Rugosochonetes extensus	+	4	4	4	+	╄	Ш	$\perp$	4	+	Ш	Щ	4	╀	╄	Ш	Ц	4	4	_	$\vdash$	Н	4	+	╄	Ш	Щ	4	+	╄	Ш	4	4	+	╄	Ш	Ц	Щ	4	+	4	┺	Н	Щ	Н	4	4	4	+	ш	Н	4
Plicatifera plicatilis	+	+	4	+	+	╀	Н	$\dashv$	+	+	Н	Н	+	+	+	Н	Н	$\rightarrow$	+	+	$\vdash$	$\vdash$	+	+	1	Н	+	+	+	╄	Н	-	+	+	╀	Н	+	$\dashv$	+	+	+	╄	Н	Н	$\dashv$	+	+	+	+	₽	$\dashv$	4
Plicatifera pseudoplicatilis	+	4	+	+	+	╀	Н	$\perp$	+	+	$\vdash$	Н	+	+	+	Н	Н	$\dashv$	+	+	$\vdash$	$\vdash$	4	+	╀	Н	Н	+	+	⊢	Н	-	4	+	⊢	Н	Н	$\dashv$	4	+	+	╄	Н	Н	$\dashv$	+	+	+	+	₽	+	4
Absenticosta uldzejtuensis	+	+	+	+	+	╀	Н	+	+	+	$\vdash$	Н	+	+	+	Н	Н	$\dashv$	+	+	$\vdash$	Н	+	+.	╀	Н	$\vdash$	+	+	⊢	Н	$\dashv$	+1	١.	⊢	Н		$\dashv$	+	+	+	1	Н	Н	$\dashv$	+	+	+	+	₽	$\dashv$	4
Alitaria konincki	+	+	+	+	+	+	Н	+	+	+	Н	Н	+	+	+	Н	Н	$\dashv$	+	+	$\vdash$	Н	+	+	+	Н	$\vdash$	+	+	⊢	Н	$\dashv$	+	+	⊢	Н	+	$\dashv$	+	+	+	⊢	Н	Н	$\dashv$	+	+	+	+	₽	+	4
Levitusia elongata sp. nov.	+	+	+	+	+.	+	$\vdash$	+	+	+	Н	Н	+	+	+	Н	Н	$\dashv$	+	+	$\vdash$	$\vdash$	+	+	+	Н	$\vdash$	+	+	⊢	Н	$\dashv$	+	+	⊢	Н	Н	$\dashv$	+	+	+	⊢	Н	Н	$\dashv$	+	+	+	+	₽	+	$\dashv$
Marginicinctus marginicinctus	+	+	+	+   -	+ +	-	-	+	+	+	Н	Н	+	+	+	Н	Н	+	+	+	$\vdash$	$\vdash$	+	+	╀	Н	Н	+	+	⊢	Н	$\dashv$	+	+.	╀.	Н	+	$\dashv$	+	+	+	⊢	Н	Н	+	+	+	+	+	₩	+	$\dashv$
Marginatia burlingtonensis	+	+	+	+++	+	+	+	+	+	+	Н	Н	<del>-</del>	+	+	Н	+	+		+	$\vdash$	$\vdash$	+	+ +	╀	+	Н	+	+	+	Н	$\rightarrow$	+	++	+	Н	+	+	+	+	+	⊢	+	Н	+	+	+	+	+	₩	+	$\dashv$
Echinoconchus punctatus	+	+	+	+	+	+	Н	+	+	+	$\vdash$	Н	+	+	+	+	+	$\rightarrow$	+ +	+	+	$\vdash$	_	+   -	+	H	$\vdash$	+	+	⊢	Н	$\rightarrow$	+	+	╀	+	+	+	+	+	+	+	+	Н	+	+	+	+	+	₩	+	$\dashv$
Pustula pustulosa	+	+	+	+	+	+	Н	+	+	+	Н	Н	-	+	+	+	+	$\rightarrow$	+	+	-	$\vdash$	_	+ +	+	+	+	+	+	$\vdash$	Н	-	+	+	+	-	Ĥ	+	+	+	+	⊢	Н	Н	+	+	+	+	+	₩	+	$\dashv$
Fluctuaria undata	-	+	+	+	+	+	Н	+	+	+	Н	Н	+	+	+	Н	+	+	+	+	+	$\vdash$	+	++*	+	++	$\overline{}$	-	+	$\vdash$	Н	$\dashv$	+	╀	+	-	-	$\rightarrow$	+	+	+	+	Н	Н	+	+	+	+	+	₩	+	$\dashv$
Striatifera angusta	+	+	+	+	+.	+	Н	+	+	+	١.	H	+	+	╀	Н	+	+	+	+	$\vdash$	$\vdash$	+	+	╀	Н	Н	+	+	⊢	Н	$\dashv$	+	+	╀.	-	+	+	+	+	+	⊢	Н	Н	+	+	+	+	+	₩	+	4
Orthotetes keokuk	+	+	+	+	+	+	Н	+	+	+	+	+	+	+	+	Н	Н	.+		+	١.	$\vdash$	+	+ +	+	Н	$\dashv$	+	+	⊢	Н	$\dashv$	+	+	+	Н	Н	+	+	+	+	+	Н	Н	+	+	+	+	+	₩	+	$\dashv$
Schellwienella radialis	+	+	+	+	+	+	Н	+	+	+	$\vdash$	Н	+	+	+	١.	Н	$\rightarrow$	+	+	+	H	-	-	-	Н.	$\rightarrow$	-	+	╀.	Н	$\rightarrow$	+	+	╀.	H	Н	+	-	+	+	+.	Н	Н	+	+	+	+	+.	₩	+	$\dashv$
Rhipidomella michelini	+	+	+	+	+	╀	Н	+	+	+	$\vdash$	Н	+.	<del>-</del>	+	+	Н	$\rightarrow$	+ +	-	+	${}$	+	+	-	-	$\rightarrow$	+ +	-	+	Н	$\rightarrow$	+	+.	+	Ĥ	Н	-	+	-	<u>+</u>	+	-	Н	+	+	+	+	_	+	+	4
Schizophoria resupinata	+	+	+ -	+	+	+	$\vdash$	$\vdash$	+	+	$\vdash$	Н	+	+	+	+	Н	$\dashv$	+ +	+	$\vdash$	$\vdash$	+	+	+	+	$\vdash$	+ +	+	+	Н	$\dashv$	+	+	+	+	Н	+	+	+	4	+	$\vdash$	Н	$\vdash$	+	+	+	++	+	+	$\dashv$
Rotaia hikoroichiensis	+	+	+	+	+	+	$\vdash$	$\vdash$	+	+	$\vdash$	Н	+	+	+	$\vdash$	Н	$\dashv$	+	+	+.	$\vdash$	+	+.	+	$\vdash$	$\vdash$	+	+	$\vdash$	Н	$\dashv$	+	+	$\vdash$	Н	Н	$\vdash$	+	+	+	+	Н	Н	$\dashv$	+	+	+	+	₽	+	$\dashv$
Cleiothyridina fimbriata	+	+	+	+	+	+	$\vdash$	$\vdash$	+	+	$\vdash$	Н	+	+	+	$\vdash$	Н	$\dashv$	+	+	+	$\vdash$	+	+	-	$\vdash$	$\vdash$	+	+	$\vdash$	Н		+	+	╀.	Н	Н	$\vdash$	+	+	+	+	$\vdash$	$\vdash \vdash$	$\dashv$	+	+	+	+	₽	+	$\dashv$
Martinia georgei	+	4	+	+	+	╀	Н	$\dashv$	+	+	$\vdash$	Н	+	╀	╀	Н	Н	4	+	1	$\vdash$	$\vdash$	+	+	1	Н	Н	+	١_	╄	Н	+	+	+	+	Н	Н	+	4	+	+	╄	Н	Н	$\dashv$	+	+	+	+	₽	$\dashv$	4
Spirifer liangchowensis	+	+	+	+	+	╀	$\vdash$	$\vdash$	+	+		Н	+	+	+	Н	Н	4	+	+	$\vdash$	$\vdash$	+	+	+	Н	Н	+	+	$\vdash$	Н	4	+	+	+	Н	Н	$\vdash$	4	+	+	+	Н	H	$\dashv$	+	+	+	+	₽	$\dashv$	$\dashv$
Imbrexia forbesi	+	4	+	+	+	+	$\vdash$	$\vdash$	+	+	+	+	+	+	+	$\vdash$	Н	$\dashv$	+	+	$\vdash$	$\vdash$	4	+	+	Н	Н	+	+	⊢	Н	-	+	+	+	-	Н	$\vdash$	4	+	+	╄	Н	+	$\dashv$	+	+	+	+	₽	$\dashv$	4
Imbrexia incertus	+	+	+	+	+	-	H	$\vdash$	+	+	Н	Н	$\perp$	+	+	Н	Н	4	+	+	$\vdash$	$\vdash$	$\dashv$	+	+	Н	Н	$\perp$	$\perp$	⊢	Н	$\dashv$	+	+	+	-	Ц	$\vdash$	4	+	+	╀	Н	Н	4	+	+	+	+	₽	$\dashv$	$\perp$
Brachythyris chouteauensis	+	4	4	4	+	+	+	LI:	+	$\perp$	$\vdash$	Ш	+	1	$\perp$	Ш	Ц	4	+	$\perp$	$\sqcup$	Н	$\dashv$	+	$\perp$	Ш	Ш	+	$\perp$	╙	Ц	4	+	+	٠.	-	Ц	Ш	4	+	$\perp$	╀	Ш	Ц	+	4	4	4	4	₽	$\dashv$	4
Torynifer asiatica	+		$\perp$	$\perp$	$\perp$	1		$\Box$	$\perp$	$\perp$	L	Ш	$\perp$	$\perp$	<u>1</u>				$\perp$	$\perp$		Ш	丄	$\perp$	$\perp$	Ш	Ш	$\perp$	$\perp$	L	+			+ +	+	Ш		+	$\perp$	$\perp$	丄	L	Ш	Ш	Ш		丄	丄	$\perp$	Ш	Ш	╝

FIGURE 24. Geographic distributions of brachiopod species of the OD2 and OD3 asemblages in the Odaira fauna.

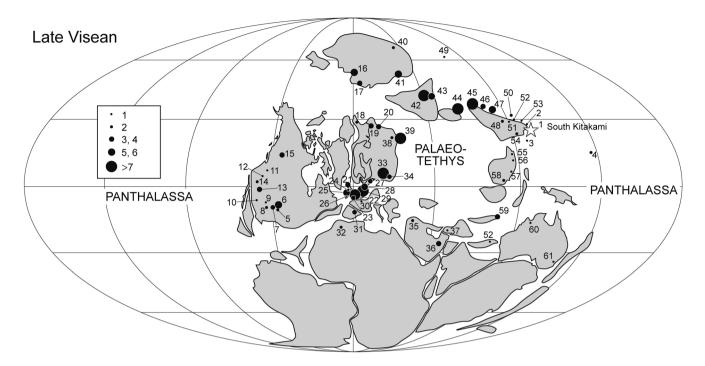


FIGURE 25. Late Visean reconstruction map of the world (adapted from Qiao and Shen, 2014), showing the geographic distributions of brachiopod species of the OD2 and OD3 assemblages in the Odaira fauna. Solid circles indicate numbers of brachiopod species listed in the OD2 and OD3 assemblages. Station numbers are same in Fig. 26.

Formation is correlated with the upper Tournaisian; the Arisu Formation is correlated with the lower Visean; and the Odaira Formation is correlated with the upper Visean. Palaeobiogeographically, the late Tournaisian (Shittakazawa) fauna resembles brachiopod assemblages of the USA (Oklahoma), the UK (England), Poland, Belgium, central Russia (Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang). The early Visean (Arisu) fauna has a close affinity with those of the UK (England), Belgium, central Russia (southern Urals and Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang), particularly with Kazakhstan and northwestern China (Xinjiang). The late Visean (Odaira) fauna displays affinities with those of the UK (England), Belgium, central Russia (southern Urals), Kazakhstan and northwestern China (Xinjiang), particularly with Kazakhstan. I conclude that the early Carboniferous (late Tournaisian-late Visean) brachiopod faunas of the central part of the South Kitakai Belt are allied with those of Kazakhstan and northwestern China (Xinjiang), and belonged to the North China Province of Yang (1983). The South Kitakami region was probably located in the eastern part of the province. During the early Carboniferous, the area was sited in the eastern part of the Central Asian Orogenic Belt and near and to the east of the North China Block as a shallow sea bordering a nicrocontinent.

### SYSTEMATIC DESCRIPTIONS

The suprageneric classification given herein mainly follows that of "Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volumes 2–6", edited by Kaesler (2000a, 2000b, 2002, 2006) and Selden (2007), with exception that classification of the suborder Productidina follows Waterhouse (2002).

Order LINGULIDA Waagen, 1885 Superfamily DISCINOIDEA Gray, 1840 Family DISCINIDAE Gray, 1840 Genus *ORBICULOIDEA* d'Orbigny, 1847

**Type species.**—Orbicula forbesii Davidson, 1848.

Orbiculoidea sp. (Fig. 36A)

**Material.**—One specimen from locality KF207, external mould of a ventral valve, NU-B2266.

**Remarks.**—This specimen is safely assigned to the genus *Orbiculoidea* by the slightly concave, subcircular ventral valve, with a narrow pedicle track near apex, and the external ornament consisting of numerous fine concentric growth lines. The ventral valve is slightly elongate subcircular in outline, gently concave and large in size for genus (length 26 mm, width 23 mm), and

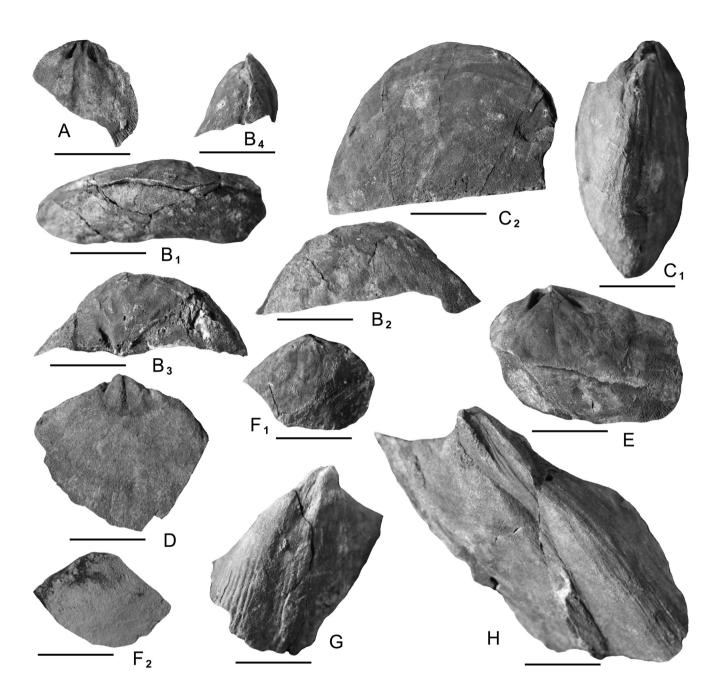


FIGURE 26. Brachiopds of the ST3 assemblage. **A,** *Rhipidomella kusbassica* Beznossova, internal mould of dorsal valve, IGPS111760; **B, C,** *Schizophoria pinguis* Demanet; dorsal (B<sub>1</sub>), anterior (B<sub>2</sub>), posterior (B<sub>3</sub>) and lateral (B<sub>4</sub>) views of internal mould of dorsal valve, IGPS99007; dorsal (C<sub>1</sub>) and lateral (C<sub>2</sub>) views of internal mould of dorsal valve, IGPS99006; **D–F**, *Schizophoria mayesensis* Carter; D, internal mould of ventral valve, IGPS111762; E, internal mould of dorsal valve, IGPS111763; internal mould (F<sub>1</sub>) and external latex cast (F<sub>2</sub>) of dorsal valve, IGPS111764; **G, H,** *Unispirifer kozuboensis* (Minato); G, internal mould of ventral valve, IGPS99008; H, internal mould of ventral valve, IGPS111761. Scale bars are 1 cm.

having a narrow, relatively short pedicle track. The single specimen from Yokota most resembles *Orbiculoidea* portlockiana Demanet (1934, p. 24, pl. 1, figs. 14–17, text-fig. 6), from the upper Tournaisian of Tournai, Belgium, in size and outline of the ventral valve. But accurate comparison is difficult for the poorly preserved specimen.

Occurrence.—AR3 Unit (Yokota).

Order STROPHOMENIDA Öpik, 1934 Superfamily STROPHOMENOIDEA King, 1846 Family RAFINESQUINIDAE Schuchert, 1893 Subfamily LEPTAENINAE Hall and Clarke, 1894 Genus *LEPTAGONIA* M'Coy, 1844

**Type species.**—*Producta analoga* Phillips, 1836.

Leptagonia analoga (Phillips, 1836) (Fig. 43A)

Producta analoga Phillips, 1836, p. 116, pl. 7, fig. 10. Strophomena rhomboidalis var. analoga Phillips. Davidson, 1861, p. 119, pl. 28, figs. 1–6, 9–13; Etheridge, 1872, p. 333, pl. 18, fig. 1.

Leptaena analoga (Phillips). Weller, 1914, p. 49, pl. 2, figs. 1–10; Frech, 1916, p. 237, pl. 2, figs. 2, 3d; Girty, 1920, pl. 54, fig. 3; Tolmatchoff, 1924, p. 209, 569. pl. 13, fig. 8; Girty, 1927, pl. 22, figs. 6–8; Demanet, 1934, p. 61, pl. 5, figs. 1–14, text-figs. 11–14; Branson, 1938, p. 24, pl. 5, fig. 31; Nelson, 1961, pl. 4, fig. 26; Sokolskaya in Sarytcheva et al., 1963, p. 80, pl. 4, figs. 9–14.

*Leptaena rhomboidalis* Wilckens. Sommer, 1909, p. 626, pl. 29, fig. 14.

*Leptagonia* cf. *analoga* (Phillips). Cvancara, 1958, p. 860, pl. 110, figs. 6–13, text-figs. 3, 4.

Leptaenella analoga (Phillips). Yang, 1964, p. 61, pl. 1, fig. 5; Grechishnikova, 1966, p. 94, pl. 1, figs. 19, 20; pl. 2, figs. 1–6; Abramov, 1970, p. 108, pl. 1, figs. 11, 12; Aisenverg and Poletaev, 1971, pl. 60, figs. 2, 3; Nalivkin and Fotieva, 1973, p. 20, pl. 1, figs. 9–13.

Leptagonia analoga (Phillips). Brunton, 1968, p. 29, pl. 3, figs. 26–31; pl. 4, figs. 1–9, text-figs. 6–17; Gaetani, 1968, p. 688, pl. 47, fig. 3; Thomas, 1971, p. 30, pl. 18, figs. 1–8, text-fig. 11; Bublichenko, 1971, p. 37, pl. 3, figs. 1–5; Brand, 1972, p. 59, pl. 8, figs. 1–6, text-figs. 1a, 3; Kalashnikov, 1974, p. 23, pl. 3, fig. 5; Litvinovich et al., 1975, p. 53, pl. 16, fig. 11; Bublichenko, 1976, p. 22, pl. 1, fig. 10; Yang et al., 1977, p. 316, pl. 131, fig. 2; Nalivkin, 1979, p. 18, pl. 3, figs. 1–3, 5, 6; Ding and Qi, 1983, p. 251, pl. 89, figs. 9, 10, 12; Zhang et al., 1983, p. 271, pl. 107, fig. 13; pl. 106, fig. 3; Tazawa et al., 1984, p. 350, pl. 67, figs. 2–4; Yang, 1984, p. 205, pl. 29, fig. 11; Xu and Yao, 1988, p. 274, pl. 67, figs. 4, 6–10; Carter, 1999, p. 96, figs. 1A–E; Shi et al., 2005, p. 39, figs. 3A, E; Tazawa et al., 2016, p. 51, fig. 5.5; Tazawa, 2017, p. 333, fig. 6.1; Tazawa, 2018c, p. 40, figs. 16B–F, 22A, B, 30A.

**Material.**—One specimen from locality KF159, external mould of a ventral valve, NU-B2154.

**Remarks.**—This specimen was described by Tazawa (2017, p. 333, fig. 6.1) as *Leptagonia analoga* (Phillips, 1836). The single specimen from Tairagai is referred to *L. analoga* (Phillips, 1836), redescribed by Brunton (1968, p. 29, pl. 3, figs. 26–31; pl. 4, figs. 1–9, text-figs. 6–17) from the Visean of England and northern Ireland, in the transversely trapezoidal and flattened ventral valve, which is ornamented with numerous fine costellae (numbering 13–15 in 5 mm at about midlength) and regularly but slightly flexuous concentric rugae. The Tairagai specimen, being smaller in size (length 23 mm, width about 34 mm) than the type specimens of *L. analoga*, may be a juvenile shell.

Occurrence.—OD3 Unit (Yokota).

**Distribution.**—Lower Tournaisian—upper Visean: northeastern Japan (Hikoroichi, Yokota and Soma in the South Kitakami Belt), USA (Illinois, Iowa, Missouri, Oklahoma, Utah and New Mexico), western Canada (Alberta), northern Russia (Verkhoyansk Range and Pechora Basin), UK (England, Isle of Man and northern Ireland), Germany, Belgium, western Russia (Donetz Basin), Turkey (Taurus Mountains), Iran (Elburz Range), central Russia (southern Urals and Kuznetsk Basin), Kazakhstan, northwestern China (Xinjiang and Gansu), central-southern China (Hubei, Guangdong and Guangxi), southwestern China (Yunnan), western Australia (Bonaparte Gulf Basin) and eastern Australia (Queensland and New South Wales).

Order PRODUCTIDA Sarytcheva and Sokolskaya, 1959 Suborder CHONETIDINA Muir-Wood, 1955 Superfamily CHONETOIDEA Bronn, 1862 Family RUGOSOCHONETIDAE Muir-Wood, 1962 Subfamily RUGOSOCHONETINAE Muir-Wood, 1962 Genus *RUGOSOCHONETES* Sokolskaya, 1950

**Type species.**—*Orthis hardrensis* Phillips, 1841.

Rugosochonetes extensus (Chao, 1928) (Fig. 43B, C)

Chonetes extensa Chao, 1928, p. 9, pl. 1, figs. 7–10; Fang in Yang et al., 1962, p. 39, pl. 12, figs. 1–6; Ding and Qi, 1983, p. 262, pl. 93, fig. 2.

Rugosochnetes extensus (Chao). Tazawa, 2017, p. 334, fig. 6.2; Tazawa in Tazawa et al., 2019, p. 51, fig. 16A.

Rugosochonetes sp. Tazawa, 1980, p. 361, pl. 41, fig. 1.

**Material.**—Three specimens from localities KF159 and YUK1: (1) external and internal moulds of a ventral valve, KCG76; (2) external and internal moulds of a dorsal valve, NU-B2172; and (3) external mould of a dorsal valve, KCG77.

**Remarks.**—One of the specimens (NU-B2172) was described by Tazawa (2017, p. 334, fig. 6.2) as *Rugosochonetes extensus* (Chao, 1928). The specimens from the upper Odaira Formation

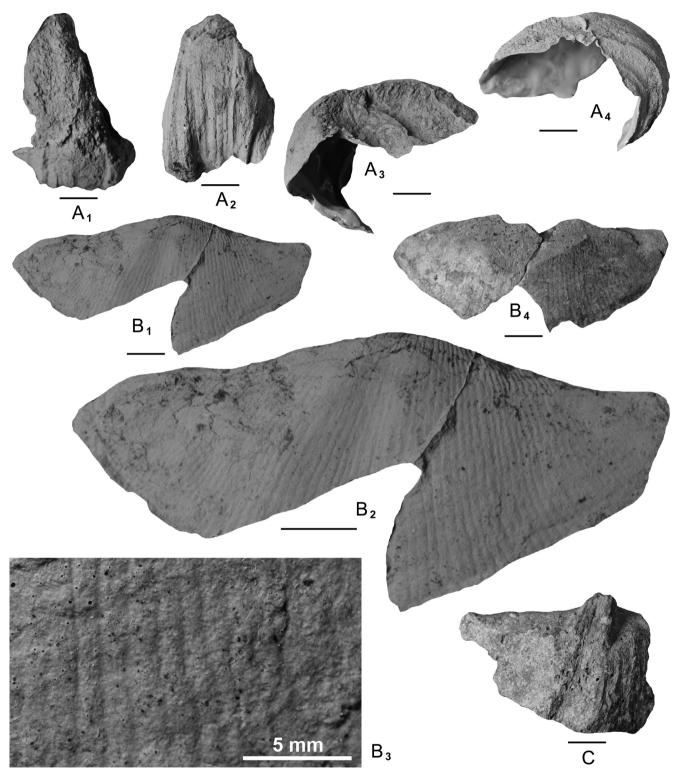


FIGURE 27. Brachiopods of the AR2 assemblage (1). **A**, *Levitusia humerosa* (Sowerby), ventral (A1), anterior (A2) and lateral (A3, A4) views of external latex cast of ventral valve, IGPS111744; **B**, **C**, *Grandispirifer mylkensis* Yang; external latex cast (B1, B2) and external mould (B4) of ventral valve, and enlarged external latex cast of ventral valve (B3) showing fine growth lines over the valve. IGPS111742; C, internal mould of ventral valve, IGPS111743. Scale bars are 1 cm, except for B3.

of Yahagi are referred to *R. extensus* (Chao, 1928), from the Chouniugou Formation of Gausu, northwestern China, by the transverse outline (length 7 mm, width 14 mm in the best preserved specimen, NU-B2172), acute cardinal extremities and external ornament consisting of numerous fine capillae (numbering 7–8 in 2 mm at about midlength). *Rugosochonetes* sp., described by Tazawa (1980, p. 361, pl. 41, fig. 1) from the upper part of the Karaumedate Formatin in the Nagasaka area, South Kitakami Belt, is conspecific with the present species. *Rugosochonetes transversalis* Brunton (1968, p. 65, pl. 9, figs. 16–25), from the Visean of County Fermanagh, northern Ireland in the UK, differs from *R. extensus* in having coarser capillae on both ventral and dorsal valves.

Occurrence.—OD3 Unit (Yahagi).

**Distribution.**—Lower-upper Visean: northeastern Japan (Yahagi and Nagasaka in the South Kitakami Belt) and northwestern China (Gansu).

Rugosochonetes sp. (Fig. 43D)

**Material.**—One specimen from locality YUK1, external mould of a ventral valve, KCG78.

Remarks.—This specimen resembles *Rugosochonetes hindi* Muir-Wood (1962, p. 70, pl. 6, figs. 1–7, text-fig. 2A), from the Serpukhovian of the UK (Scotland, England and Wales), in the medium-sized, slightly transverse shell (length 11 mm, width 13 mm) and fine capillae (numbering 6–7 in 1 mm at midlength) on the ventral valve. Accurate comparison is, however, difficult for the poorly preserved specimen. *Rugosochonetes hardlensis* (Phillips, 1841), refigured by Muir-Wood (1962, pl. 2, figs. 7–10, 13) from the upper Visean of Yorkshire, England, differs from the present species in being more transverse outline. The preceding species, *Rugosochonetes extensus* (Chao, 1928), is readily distinguished from the present species in the much transverse outline and in having coarser capillae on the ventral valve.

Occurrence.—OD3 Unit (Yahagi).

Suborder PRODUCTIDINA Waagen, 1883 Superfamily PRODUCTELLOIDEA Schuchert in Schuchert and LeVene, 1929

Family OVERTONIIDAE Muir-Wood and Cooper, 1960 Subfamily PLICATIFERINAE Muir-Wood and Cooper, 1960 Genus *PLICATIFERA* Chao, 1927

**Type species.**—*Productus plicatilis* Sowerby, 1824.

Plicatifera plicatilis (Sowerby, 1824) (Fig. 43F)

Productus plicatilis Sowerby, 1824, p. 85, pl. 459, fig. 2;
Thomas, 1914, p. 331, pl. 20, fig. 22, text-fig. 13.
Plicatifera plicatilis (Sowerby). Muir-Wood and Cooper, 1960, pl. 56, figs. 13–23; Galitskaya, 1977, p. 22, pl. 8, figs. 6, 7;

Zakowa, 1985, p. 306, pl. 1, figs. 5–7; pl. 2, figs. 1–3; pl. 5, fig. 5; Brunton and Mundy in Brunton et al., 1993, p. 108, figs. 29–35.

*Productus-Plicatifera-plicatilis* Sowerby. Pareyn, 1961, p. 209, pl. 26, fig. 5.

**Material.**—Two specimens from locality YUK1, external moulds of two ventral valves, KCG65, 66.

Remarks.—The fragmentarily preserved specimens from Yahagi can be referred to *Plicatifera plicatilis* (Sowerby, 1824), redescribed by Brunton and Mundy in Brunton et al. (1993, p. 108, figs. 19–35) from the upper Visean of Derbyshire and Yorkshire, England, by the medium-sized, transverse and gently convex ventral valve (length about 25 mm, width about 50 mm in the better preserved specimen, KCG65), and external ornament of the ventral valve consisting of numerous regular concentric rugae on visceral disc and numerous small spines scattered on rugae. *Plicatifera pseudoplicatilis* (Muir-Wood, 1928, p. 189, pl. 11, fig. 17, text-fig. 34), from the upper Visean of Staffordshire, England, differs from *P. plicatilis* in having numerous costellae on the visceral disc and trail of the ventral valve.

Occurrence.—OD3 Unit (Yahagi).

**Distribution.**—Upper Visean: northeastern Japan (Yahagi in the South Kitakami Belt), UK (England), Poland, Belgium, Algeria and Kyrgyzstan.

Plicatifera pseudoplicatilis (Muir-Wood, 1928) (Fig. 43E)

Productus pseudoplicatilis Muir-Wood, 1928, p. 189, pl. 11, fig. 17, text-fig. 34; Kalashnikov, 1974, p. 69, pl. 20, figs. 9–11. Plicatifera plicatilis (non Sowerby). Brunton, 1966, p. 204, pl. 6, figs. 6–15; pl. 7, figs. 1–18, text-fig. 8.

*Plicatifera pseudoplicatilis* (Muir-Wood). Brunton and Mundy in Brunton et al., 1993, p. 109, figs. 36–46.

**Material.**—One specimen from locality YUK1, external mould of a dorsal valve, KCG70.

**Remarks.**—This specimen can be referred to *Plicatifera* pseudoplicatilis (Muir-Wood, 1928), from the upper Visean of Staffordshire and Yorkshire, England, by the presence of numerous fine costellae over the visceral disc and trail of the dorsal valve. The preceding species, *Plicatifera* plicatilis (Sowerby, 1824), differs from *P. pseudoplicatilis* in the lacking costellae on the dorsal valve.

Occurrence.—OD3 Unit (Yahagi).

**Distribution.**—Lower–upper Visean: northeastern Japan (Yahagi in the South Kitakami Belt), northern Russia (northern Urals) and UK (England).

Genus ABSENTICOSTA Lazarev, 1991

**Type species.**—Absenticosta uldzejtuensis Suursuren and Lazarev in Lazarev, 1991

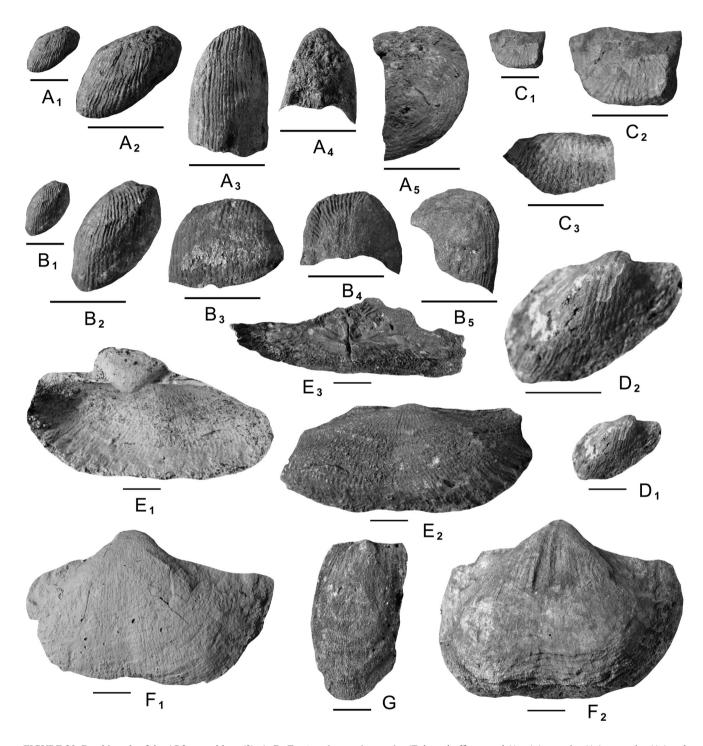


FIGURE 28. Brachiopods of the AR2 assemblage (2). **A–D**, *Tomiproductus elegantulus* (Tolmatchoff); ventral (A<sub>1</sub>, A<sub>2</sub>), anterior (A<sub>3</sub>), posterior (A<sub>4</sub>) and lateral (A<sub>5</sub>) views of internal mould of ventral valve, IGPS112115; ventral (B<sub>1</sub>, B<sub>2</sub>), anterior (B<sub>3</sub>), posterior (B<sub>4</sub>) and lateral (B<sub>5</sub>) views of internal mould of ventral valve, IGPS112118; dorsal (C<sub>1</sub>, C<sub>2</sub>) and anterior (C<sub>3</sub>) views of external mould of dorsal valve, IGPS112119; D<sub>1</sub>, D<sub>2</sub>, internal mould of ventral valve, NU-B2262; **E, F**, *Tolmatchoffia robusta* (Tolmatchoff), external latex cast (E<sub>1</sub>), external mould (E<sub>2</sub>) and internal mould (E<sub>3</sub>) of dorsal valve, IGPS112098; external latex cast (F<sub>1</sub>) and internal mould (F<sub>2</sub>) of ventral valve, IGPS112097; **G**, *Ovatia elongata* Muir-Wood and Cooper, external mould of dorsal valve, IGPS11725. Scale bars are 1 cm.

Absenticosta uldzejtuensis Suursuren and Lazarev in Lazarev, 1991 (Fig. 38A, B)

*Plicatifera plicatilis* (Sowerby). Kotlyar in Kotlyar and Popeko, 1967, p. 95, pl. 15, figs. 16–18; pl. 16, figs. 1–3.

Absenticosta uldzejtuensis Suursuren and Lazarev in Lazarev, 1991, p. 58, pl. 4, figs. 1–6; Lazarev and Suursuren, 1992, p. 64, pl. 14, figs. 14–17.

**Material.**—Five specimens from localities AOD1 and YKA20: (1) internal mould of a ventral valve, IGPS112133; and (2) external moulds of four dorsal valves, IGPS112134–112136, NU-B2242.

Remarks.—These specimens are referred to Absenticosta uldzejtuensis Suursuren and Lazarev in Lazarev, 1991, from the upper Visean of the Khangay Highland, Mongolia, in the small, slightly transverse and gently convex ventral valve (length about 11 mm, width about 14 mm in the sole ventral valve specimen, IGPS112133), ornamented with numerous thin, somewhat irregular concentric rugae (numbering 5–6 in 2 mm at about midlength) on entire surface of the valve. Absenticosta bruntoneileenae Taboada and Shi (2011, p. 105, fig. 12), from the upper Visean of the Uspallata-Iglesia Basin, western Argentina, is distinguished from A. uldzejtuensis in the larger and less transverse shell.

Occurrence.—OD2 Unit (Yokota and Shizu).

**Distribution.**—Upper Visean: northeastern Japan (Yokota and Shizu in the South Kitakami Belt), eastern Russia (Transbaykal) and Mongolia (Khangay Highland).

Family PRODUCTINIDAE Muir-Wood and Cooper, 1960 Subfamily PRODUCTININAE Muir-Wood and Cooper, 1960 Genus *ARGENTIPRODUCTUS* Cooper and Muir-Wood, 1951

**Type species.**—*Productus margaritacea* Phillips, 1836.

Argentiproductus sp. (Fig. 43G)

**Material.**—Two specimens from locality YUK1, external moulds of two dorsal valves, KCG63, 64.

Remarks.—These specimens are safely assigned to the genus Argentiproductus by the external ornament of dorsal valve, consisting of numerous irregular rounded costae and closely placed concentric lamellae. The type species, Argentiproductus margaritaceus (Phillips, 1836), refigured by Muir-Wood and Cooper (1960, pl. 123, figs. 11–17) from the Visean of northern Ireland and Wales, the UK, is more transverse in outline. Argentiproductus auriculatus Carter (1988, p. 38, figs. 6.33–6.50), from the Glen Park Formation of Illinois, is a smaller and more transverse species. Specific identification is difficult for the poorly preserved specimens.

Occurrence.—OD3 Unit (Yahagi).

Superfamily MARGINIFEROIDEA Stehli, 1954
Family PAUCISPINIFERIDAE Muir-Wood and Cooper, 1960
Subfamily PAUCISPINIFERINAE Muir-Wood and Cooper, 1960

Genus ALITARIA Cooper and Muir-Wood, 1967

**Type species.**—Alifera konincki Muir-Wood and Cooper, 1960.

Alitaria konincki (Muir-Wood and Cooper, 1960) (Fig. 43H–J)

Productus expansus de Koninck, 1842, p. 159, pl. 7, fig. 4.
Alifera konincki Muir-Wood and Cooper, 1960, p. 208, pl. 66, figs. 6–18; Galitskaya, 1977, p. 50, pl. 13, figs. 12–17.
Alitaria konincki (Muir-Wood and Cooper). Cooper and Muir-Wood, 1967, p. 808.

**Material.**—Three specimens from locality YUK1: (1) internal mould of a conjoined valve, with external mould of the dorsal valve, KCG71; and (2) internal moulds of two ventral valves, KCG72, 73.

**Remarks.**—These specimens are fragmentarily preserved, but can be referred to *Alitaria konincki* (Muir-Wood and Cooper, 1960, p. 208, pl. 66, figs. 6–18), from the Visean of Visé, Belgium, by the small and transverse shell (length 13 mm, width more than 18 mm in the best preserved specimen, KCG71), with a prominent marginal ridge in the ventral valve. *Alitaria minuta* (Muir-Wood, 1928, p. 195, pl. 12, fig. 3), from the upper Tournaisian (?)—upper Visean of England and Ireland, differs from *A. konincki* in the smaller size and finer costation.

Occurrence.—OD3 Unit (Yahagi).

**Distribution.**—Lower Visean–Serpukhovian: northeastern Japan (Yahagi in the South Kitakami Belt), Belgium and Kyrgyzstan.

Superfamily HORRIDONIOIDEA Muir-Wood and Cooper, 1960

Family LEIOPRODUCTIDAE Muir-Wood and Cooper, 1960 Subfamily LEVITUSIINAE Muir-Wood and Cooper, 1960 Genus *LEVITUSIA* Muir-Wood and Cooper, 1960

**Type species.**—*Productus humerosus* Sowerby, 1822.

Levitusia humerosa (Sowerby, 1822) (Fig. 27A)

*Productus humerosus* Sowerby, 1822, p. 21, fig. 322; Davidson, 1861, p. 147, pl. 36, figs. 1, 2; Yanishevsky, 1918, p. 38, pl. 3, figs. 1–5.

*Productus sublaevis* de Koninck. Davidson, 1861, p. 177, pl. 31, figs. 1, 2; pl. 32, fig. 1; pl. 51, figs. 1, 2; Rotai, 1931, p. 50, pl. 1, figs. 7, 8; pl. 2, figs. 1, 5.

Productus (Plicatifera) humerosus Sowerby. Paeckelmann, 1931, p. 120, pl. 6, fig. 5; pl. 7, figs. 1-4; pl. 8, figs. 1-3; pl.

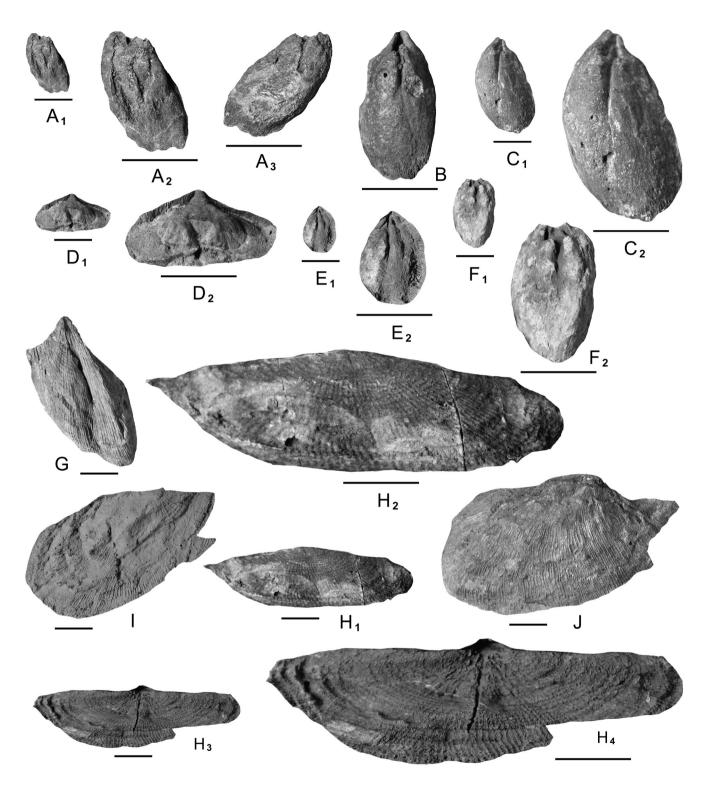


FIGURE 29. Brachiopods of the AR2 assemblage (3). **A–F**, *Rhipidomella michelini* (Léveillé); ventral (A<sub>1</sub>, A<sub>2</sub>) and dorsal (A<sub>3</sub>) views of internal moud of conjoined shell, IGPS111721; B, internal mould of dorsal valve, IGPS111724; C<sub>1</sub>, C<sub>2</sub>, internal mould of dorsal valve, NU-B2256; D<sub>1</sub>, D<sub>2</sub>, internal mould of ventral valve, IGPS112100; E<sub>1</sub>, E<sub>2</sub>, internal mould of dorsal valve, IGPS112103; F<sub>1</sub>, F<sub>2</sub>, internal mould of dorsal valve, IGPS112104; **G**, **H**, *Marginatia burlingtonensis* (Hall); G, internal mould of vental valve, NU-B2258; ventral (H<sub>1</sub>, H<sub>2</sub>) and dorsal (H<sub>3</sub>, H<sub>4</sub>) views of internal mould of conjoined shell, NU-B2260; **I**, *J*, *Orthotetes keokuk* (Hall); I, external latex cast of ventral valve, IGPS112120; J, internal mould of dorsal valve, IGPS112121. Scale bars are 1 cm.

11, fig. 1; Rotai, 1941, p. 96, pl. 17, figs. 3-6.

Productus (Plicatifera) humerosus var. longa Paeckelmann, 1931, p. 128, pl. 9, fig. 1.

Productus (Plicatifera) humerosus var. christiani de Koninck. Paeckelmann, 1931, p. 131, pl. 10, fig. 1; pl. 12, fig. 4; pl. 13, fig. 1.

Levitusia humerosa (Sowerby). Muir-Wood and Cooper, 1960, pl. 109, figs. 2–5; pl. 110, figs. 1–5; Nalivkin and Fotieva, 1973, p. 43, pl. 9, figs. 4, 5: Garanj et al., 1975, p. 181, pl. 78, fig. 2; pl. 80, fig. 5; Galitskaya, 1977, p. 123, pl. 12, figs. 4–7; pl. 38, fig. 1; Brunton, 1979, p. 7, pl. 1, figs. 1–6; pl. 2, figs. 1–5; pl. 4, figs. 1–4; Nalivkin, 1979, p. 59, pl. 18, fig. 6; Tazawa and Kurita, 2019b, p. 194, fig. 3.

Levitusia christiani uralica Fotieva in Nalivkin and Fotieva, 1973, p. 44, pl. 10, figs. 1, 2.

**Material.**—One specimen from locality KAR11, external mould of a ventral valve, IGPS111744.

Remarks.—This specimen was described by Tazawa and Kurita (2019b, p. 194, fig. 3) as Levitusia humerosa (Sowerby, 1822). The specimen, from the middle part of the Arisu Formation (AR2 Unit) of Okuhinotsuchi in the South Kitakami Belt, is poorly preserved, but can be referred to L. humerosa (Sowerby, 1822), redescribed by Brunton (1979, p. 7, pl. 1, figs. 1-6; pl. 2, figs. 1-5; pl. 4, figs. 1-4) on the type specimens from the lower Visean of Belgium and Staffordshire, England, in the large, strongly convex ventral valve (length more than 45 mm; width more than 35 mm), with long sulcated trail, and the external ornament consisting of irregular rugae on visceral portion and several strong longitudinal flutings on trail. Levitusia sublaevis (de Koninck, 1843), redescribed by Brunton (1979, p. 12, pl. 3, figs. 1–9; pl. 4, figs. 5, 6) from the lower Visean of Belgium and Lancashire, England, differs from L. humesosa in having weaker posterior rugation and shallower ventral sulcus.

Occurrence.—AR2 Unit (Okuhinotsuchi).

**Distribution.**—Lower Visean: northeastern Japan (Okuhinotsuchi in the South Kitakami Belt), the UK (England), Germany, Belgium, western Russia (Donetz Basin), central Russia (western and southern Urals), Uzbekistan (Fergana) and Kyrgyzstan (northern Tian-Shan).

Levitusia elongata sp. nov. (Fig. 38F, G)

**Etymology.**—In reference to elongate outline of the species. **Material.**— Four specimens from localities INS7, INS11, YKA12 and YKA21: (1) external and internal moulds of a conjoined shell, IGPS112155; (2) external and internal moulds of a ventral valve, IGPS112154 (holotype); and (3) internal moulds of two ventral valves, IGPS112156, 112157.

**Diagnosis.**—Medium-sized, elongate *Levitusia*, with a well-developed ventral sulcus and strong reticulate ornament on ventral valve.

Description.—Shell medium in size for genus, elongate

subrectangular in outline, widest at hinge; length about 67 mm, width about 32 mm in the holotype (IGPS112154). Ventral valve strongly convex in lateral profile, with a long trail; umbo small, strongly incurved; ears large, trigonal and nearly flattened; sulcus narrow and deep. External surface of ventral valve ornamented with strong rugae and fine costae on visceral disc, but costae only on trail; numbering 4 rugae in 10 mm, 7–8 costae in 5 mm on visceral disc, and 7 costae in 5 mm on trail. Internal structures of both valves not well-preserved, although ventral valve having widely diverging, anterior ridged diductor scars, and dorsal valve having large trilobate cardinal process and elevated adductor scars.

Remarks.—Levitusia elongata sp. nov. is distinguished from the type species, Levitusia humerosa (Sowerby, 1822), in the smaller size, less transverse outline and in having well-developed sulcus on the ventral valve. Levitusia spinauris Brunton (1979, p. 14, pl. 2, figs. 6–8), from the lower Visean of Staffordshire, England, differs from the present new species in having shallower ventral sulcus, and finer costellae on ventral valve. Levitusia sublaevis (de Koninck, 1843), redescribed by Brunton (1979, p. 12, pl. 3, figs. 1–9; pl. 4, figs. 5, 6), from the lower Visean of Belgium (Visé) and, England (Lancashire), differs from L. elongata sp. nov. in its much transverse outline.

Occurrence.—OD2 Unit (Nisawa and Shizu).

**Distribution.**—Upper Visean: northeastern Japan (Nisawa and Shizu in the South Kitakami Belt).

Superfamily PRODUCTOIDEA Gray, 1840
Family BUXTONIIDAE Muir-Wood and Cooper, 1960
Subfamily BUXTONIINAE Muir-Wood and Cooper, 1960
Genus TOLMATCHOFFIA Fredericks, 1933

Type species.— Productus robustus Tolmatchoff, 1924.

Tolmatchoffia robusta (Tolmatchoff, 1924) ( Fig. 28E, F)

*Productus robustus* Tolmatchoff, 1924, p. 230, 572, pl. 13, fig. 17; pl. 14, figs. 1–3.

*Dictyoclostus robustus* (Tolmatchoff). Benediktova, 1955, p. 309, pl. 85, fig. 6; Yang, 1964, p. 96, pl. 9, figs. 6, 7.

Tolmatchoffia robusta (Tolmatchoff). Muir-Wood and Cooper, 1960, pl. 95, figs. 1–3; Sarytcheva in Sarytcheva et al., 1963, p. 171, pl. 21, figs. 1–3; pl. 22, figs. 1–3, text-figs. 71, 72; Galitskaya, 1977, p. 74, pl. 34, fig. 3; Zhang et al., 1983, p. 302, pl. 118, figs. 4, 5; Tazawa, 2018c, p. 44, figs. 17A–F, 22G–J. Buxtonia sp. Tazawa, 1989, p. 60, pl. 1, figs. 6–9.

Material.—Five specimens from locality KF179 and KF181: (1) internal mould of a conjoined shell with external mould of the dorsal valve, IGPS112122; (2) external and internal moulds of a ventral valve, IGPS112097; (3) external and internal moulds of two dorsal valves, IGPS112098, 112123; and (4) external mould of a dorsal valve, IGPS112099.

Remarks.—These specimens are referred to Tolmatchoffia

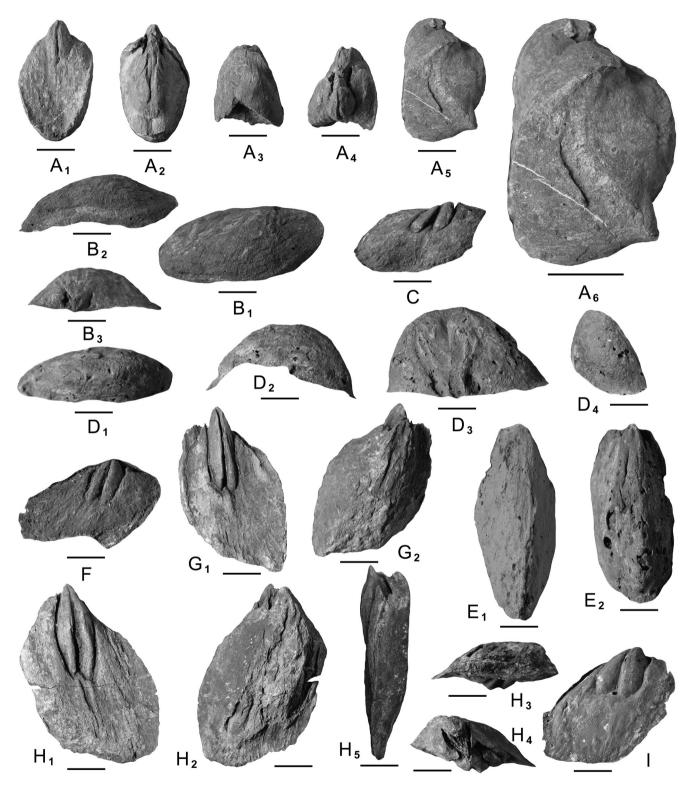


FIGURE 30. Brachiopods of the AR2 assemblage (4). **A,** *Schizophoria woodi* Bond, ventral (A1), dorsal (A2), anterior (A3), posterior (A4) and lateral (A5, A6) views of internal mould of conjoined shell, IGPS111728; **B–E**, *Schizophoria pinguis* Demanet; ventral (B1), anterior (B2) and posterior (B3) views of internal mould of dorsal valve, IGPS111730; C, internal mould of ventral valve, IGPS112085; dorsal (D1), anterior (D2), posterior (D3) and lateral (D4) views of internal mould of dorsal valve, IGPS112087; external latex cast (E1) and internal mould (E2) of dorsal valve, IGPS111729; **F–I**, *Schizophoria resupinata* (Martin); F, internal mould of ventral valve, IGPS112106; ventral (G1) and dorsal (G2) views of internal mould of conjoined shell, IGPS111715; I, internal mould of ventral valve, IGPS112105. Scale bars are 1 cm.

robusta (Tolmatchoff, 1924), redescribed by Sarytcheva in Sarytcheva et al. (1963, p. 171, pl. 21, figs. 1–3; pl. 22, figs. 1–3, text-figs. 71, 72) from the lower and upper Tournaisian of the Kuznetsk Basin, central Russia, in the large size (length 45 mm, width 68 mm in the ventral valve specimen, IGPS112097), distinct sulcus and numerous costae (numbering 7 in 5 mm in the midlength) on the ventral valve. Tolmatchoffia barzassica Sarytcheva in Sarytcheva et al. (1963, p. 174, pl. 23, figs. 1, 2, text-fig. 73), from the lower and upper Tournasian of the Kuznetsk Basin, differs from T. robusta in its smaller size and in having no ventral sulcus.

Occurrence.—AR2 Unit (Yokota).

**Distribution.**—Lower Tournaisian—lower Visean: northeastern Japan (Yokota in the South Kitakami Belt), central Russia (Kuznetsk Basin), Kyrgyzstan and northwestern China (Xinjiang).

Genus *TOMIPRODUCTUS* Sarytcheva in Sarytcheva, Sololskaya, Besnossova and Maksimova, 1963

Type species.—Productus elegantulus Tolmatchoff, 1924.

Tomiproductus elegantulus (Tolmatchoff, 1924) (Fig. 28A–D)

*Productus elegantulus* Tolmatchoff, 1924, p. 244, 579, pl. 14, figs. 5–7.

Tomiproductus elegantulus (Tolmatchoff). Sarytcheva in Sarytcheva et al., 1963, p. 202, pl. 31, figs. 1–11; pl. 32, figs. 1–7, text-figs. 88, 89; Nalivkin and Fotieva, 1973, p. 42, pl. 8, figs. 12, 13; Kalashnikov, 1974, p. 55, pl. 13, fig. 6; Bublichenko, 1976, p. 54, pl. 3, fig. 9; pl. 5, figs. 1, 2; Bahrammanesh et al., 2011, p. 145, fig. 5k-q; Tazawa and Ibaraki, 2019, p. 13, fig. 4A.

Material.—Seven specimens from localities IYK1, IYK2, KF179, KF180 and KF181: (1) external and internal moulds of a ventral valve, IGPS112115; (2) internal moulds of three ventral valves, IGPS112116–112118; (3) external mould of a dorsal valve, IGPS112119; and (4) internal moulds of two ventral valves, NU-B2262, 2263.

Remarks.—Two specimens (NU-B2262, 2263) from the middle Arisu Formation of Yokota were described by Tazawa and Ibaraki (2019, p. 13, fig. 4A) as *Tomiproductus elegantulus* (Tolmatchoff, 1924). All the other specimens are also referred to *Tomiproductus elegantulus* (Tolmatchoff, 1924), redescribed by Sarytcheva in Sarytcheva et al. (1963, p. 202, pl. 31, figs. 1–11; pl. 32, figs. 1–7, text-figs, 88, 89) from the lower–upper Tournaisian of the Kuznetsk Basin, central Russia, in their small size (length 10 mm, width 17 mm in the largest specimen, IGPS112115; length 15 mm, width 11 mm in the best preserved ventral valve specimen, IGPS112117), strongly inflated ventral valve with a long trail, dorsal valve with flat disc, strongly geniculated and followed by a long trail, numerous fine costellae on entire surface of both valves (10–12 in 5 mm on ventral trail),

and weak concentric rugae on discs of both valves. *Tomiproductus minimus* (Demanet, 1921), redescribed by Nalivkin (1979, p. 91, pl. 13, fig. 26; pl. 31, figs. 1–11) from the upper Tournaisian–middle Visean of the northern Urals, is also a small-sized *Tomiproductus*, but it differs from *T. elegantulus* in having stronger rugae on dorsal disc. *Tomiproductus kollari* Carter (1990, p. 224, figs. 3.1–3.14), from the middle–upper Keokuk Limestone of Missouri, USA, differs from *T. elegantulus* in the slightly larger size and coarser rugae on ventral valve.

Occurrence.—AR2 Unit (Yokota).

**Distribution.**—Lower Tournaisian—upper Visean: northeastern Japan (Yokota in the South Kitakami Belt), northern Russia (Pechora Basin), Iran, central Russia (western Urals and Kuznetsk Basin) and Kazakhstan (Altay Mountains).

Genus MARGINICINCTUS Sutton, 1938

**Type species.**—*Productus marginicinctus* Prout, 1857.

Marginicinctus marginicinctus (Prout, 1857) (Figs. 38C, D, 44A)

Productus marginicinctus Prout, 1857, p. 43, pl. 2, figs. 1–6;Weller, 1914, p. 127, pl. 13, figs. 18–23.

*Marginicinctus marginicinctus* (Prout). Sutton, 1938, p. 63, figs. 5–8; Muir-Wood and Cooper, 1960, pl. 75, figs. 10–12; pl. 76, figs. 1–11, 17–20.

*Marginicinctus* sp. Tazawa, Itabashi and Mori, 1981, pl. 1, figs. 7–10; Tazawa, 1981b, p. 71, pl. 5, fig. 2.

*Marginicinctus* cf. *marginicinctus* (Prout). Tazawa, 1981b, p. 70, pl. 5, fig. 1.

**Material.**—Four specimens from localities INS3, INS13 and KF210: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, IGPS97656; and (2) internal mould of three ventral valves, IGPS97657, 97658, NU-B2330.

Remarks.—Most of the specimens from Nisawa were previously figured by Tazawa et al. (1981, pl. 1, figs. 7–10) and Tazawa (1981b, p. 71, pl. 5, fig. 2) as Marginicinctus sp., and described by Tazawa (1981b, p. 70, pl. 5, fig. 1) as Marginicinctus cf. marginicinctus (Prout, 1857). But the Nisawa specimens are referred to Marginicinctus marginicinctus (Prout, 1857), redescribed and refigured by Weller (1914, p. 127, pl. 13, figs. 18–23) from the St. Louis Limestone of Missouri, in size, shape and external ornament of the both ventral and dorsal valves. In the present article a ventral valve specimen (NU-B2330), from the uppermost part of the Odaira Formation at Yukisawa, is added to the material. Marginicinctus reticulatus Roberts (1976, p. 66, pl. 11, figs. 1–12), from the upper Visean of eastern Australia, differs from M. marginicinctus in the larger size and the stronger rugae on the both ventral and dorsal valves.

Occurrence.—OD2 Unit (Nisawa) and OD3 Unit (Yahagi).

**Distribution.**—Upper Visean: northeastern Japan (Yahagi and Nisawa in the South Kitakami Belt) and USA (Iowa and Missouri).

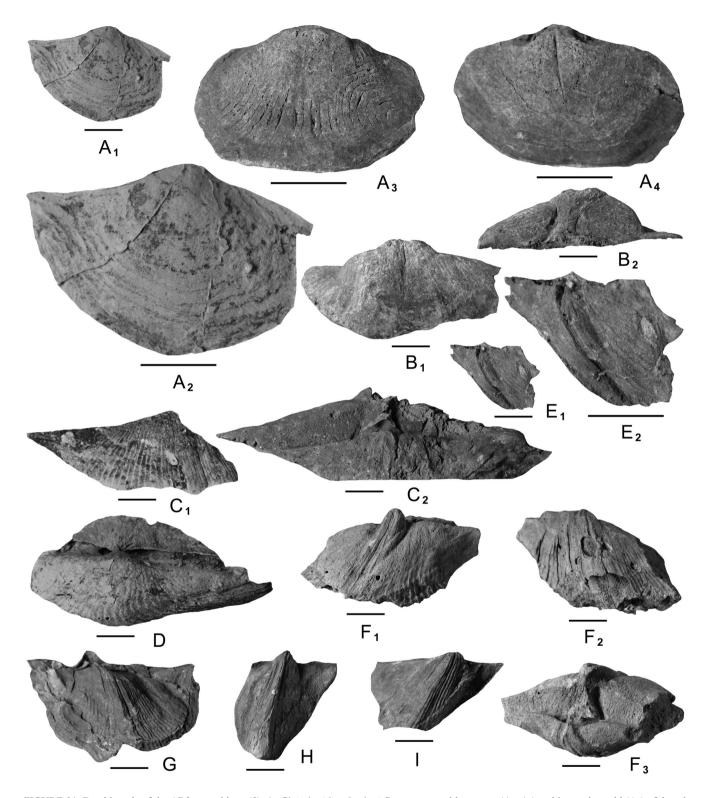


FIGURE 31. Brachiopods of the AR2 assemblage (5). **A,** *Cleiothyridina harkeri* Carter, external latex cast (A<sub>1</sub>, A<sub>2</sub>) and internal mould (A<sub>4</sub>) of dorsal valve, and internal mould (A<sub>3</sub>) of ventral valve of conjoined shell, NU-B2265; **B-D,** *Unispirifer striatoconvolutus* (Dun and Benson); ventral (B<sub>1</sub>) and posterior (B<sub>2</sub>) views of internal mould of ventral valve, IGPS111733; external latex cast of dorsal valve (C<sub>1</sub>) and posterior view of internal mould (C<sub>2</sub>) of conjoined shell, IGPS112094; D, external latex cast of dorsal valve, IGPS112095; **E,** *Unispirifer* sp., ventral view (E<sub>1</sub>, E<sub>2</sub>) of internal mould of ventral valve, IGPS111734; **F-I,** *Unispirifer kozuboensis* (Minato); ventral (F<sub>1</sub>), dorsal (F<sub>2</sub>) and posterior (F<sub>3</sub>) views of internal mould of conjoined shell, IGPS112091; G, internal mould of dorsal valve, IGPS112113; H, internal mould of dorsal valve, IGPS112093; I, internal mould of dorsal valve, IGPS112127. Scale bars are 1 cm.

Subfamily MARGINATIINAE Waterhouse, 2002 Genus MARGINATIA Muir-Wood and Cooper, 1960

**Type species.**—*Productus fernglenensis* Weller, 1909.

Marginatia burlingtonensis (Hall, 1858) (Figs. 29G, H, 36B, C, 44B–D)

*Productus flemingi* var. *burlingtonensis* Hall, 1858, p. 598, pl. 12, fig. 3.

*Productus burlingtonensis* Hall. Weller, 1914, p. 104, pl. 9, figs. 1–10; Frech, 1916, p. 239, pl. 6, fig. 1; Tolmatchoff, 1924, p. 237, 575, pl. 14, figs. 8–11; Girty, 1929, p. 85, pl. 9, figs. 20–24.

*Productus* (*Productus*) *burlingtonensis* Hall. Nalivkin, 1937, p. 66, pl. 7, figs. 7–11.

Productus sp. Minato, 1951, p. 366, pl. 1, fig. 4.

*Productus* (*Dictyoclostus*) burlingtonensis Hall. Simorin, 1956, p. 136, pl. 9, figs. 1–3.

Marginatia burlingtonensis (Hall). Sarytcheva in Sarytcheva et al., 1963, p. 191, pl. 28, figs. 5–8, text-figs. 81, 82; Grechishnikova, 1966, p. 116, pl. 8, figs. 11–13; Aksenova in Litvinovich et al., 1969, p. 213, pl. 35, figs. 2–4; Nalivkin and Fotieva, 1973, p. 39, pl. 8, fig. 1; Bublichenko, 1976, p. 50, pl. 2, fig. 12; pl. 4, fig. 6; pl. 5, figs. 4–6; pl. 6, fig. 9; Galitskaya, 1977, p. 83, pl. 22, figs. 6–10; Nalivkin, 1979, p. 94, pl. 32, figs. 1–10; pl. 34, figs. 3, 4; Lee et al., 1980, p. 368, pl. 148, fig. 10; Jin, 1985, p. 77, pl. 1, figs. 20–22; Carter, 1987, p. 39, pl. 9, figs. 1–8; Shi et al., 2005, p. 44, figs. 5D, I–K, M; Tazawa, 2006, p. 132, figs. 6.1–6.8; Tazawa, 2017, p. 335, figs. 6.3–6.5; Tazawa, 2018c, p. 44, figs. 23A–D; Tazawa and Ibaraki, 2019, p. 14, figs. 4C, D.

*Dictyoclostus* sp. Hase and Yokoyama, 1975, pl. 18, fig. 1. *Marginatia* sp. Tazawa, 1985, p. 459, figs. 2.3–2.7; Tazawa, 1989, p. 60, pl. 1, fig. 1; Tazawa, 2002, figs. 7.1, 7.2.

Material.—Ten specimens from localities IYK2, IYK3, KF159, KF207, KF208 and KYT3: (1) external and internal moulds of a ventral valve, NU-B630; (2) external mould of two ventral valves, IGPS112132, NU-B2160; (3) internal moulds of four ventral valves, NU-B650, 2161, 2258, 2259; (4) external and internal moulds of a dorsal valve, NU-B2260; and (5) external moulds of two dorsal valves, NU-B2162, 2261.

Remarks.—Most of the specimens were described by Tazawa (2006, 2017) and Tazawa and Ibaraki (2019) as Marginatia burlingtonensis (Hall). These specimens are fragmentarily preserved or severely squashed, but can be referred to Marginatia burlingtonensis (Hall, 1858), from the Burlington Limestone of Illinois and Iowa, by the medium size (length about 20 mm, width about 46 mm in the best preserved ventral valve specimen, NU-B2160), strongly geniculated ventral valve, reticulate ornament on visceral discs of both valves, and two symmetrically arranged strong halteroid spines on ventral trail. Marginatia patersonensis Roberts (1965, p. 63, pl. 10, figs. 1–5), from the lower and upper Visean of New

South Wales, eastern Australia, differs from the present species in having finer costae and larger number of spines on the ventral valve. The type species, *Marginatia fernglenensis* Weller (1909, p. 299, pl. 12, figs. 14–17) from the Fern Glen Formation of Missouri, differs from *M. burlingtonensis* in having shallower ventral sulcus.

Occurrence.—AR2, AR3 and OD3 units (Yokota).

**Distribution.**—Upper Tournaisian—upper Visean: northeastern Japan (Hikoroichi and Yokota in the South Kitakami Belt), southwestern Japan (Hina in the Akiyoshi Belt), USA (Illinois, Iowa and Arkansas), western Canada (Alberta), Turkey (Taurus Mountains), central Russia (southern Urals and Kuznetsk Basin), Kazakhstan, Kyrgyzstan and northeastern China (Liaoning).

Superfamily ECHINOCONCHOIDEA Stehli, 1954 Family ECHINOCONCHIDAE Stehli, 1954 Subfamily ECHINOCONCHINAE Stehli, 1954 Genus *ECHINOCONCHUS* Weller, 1914

**Type species.**—*Productus punctatus* Sowerby, 1822.

Echinoconchus punctatus (Sowerby, 1822) (Fig. 44G, H)

*Productus punctatus* Martin. Sowerby, 1822, p. 22, pl. 323, lower right figure; Davidson, 1861, p. 172, pl. 44, figs. 9–11, 16, 17.

*Pustula punctata* (Martin). Thomas, 1914, p. 303, pl. 17, figs. 16–19, text-fig. 11; Tolmatchoff, 1924, p. 256, 584, pl. 16, fig. 9; Rotai, 1931, p. 58, pl. 4, figs. 1, 11.

*Productus (Pustula) punctatus* (Martin). Yanishevsky, 1918, p. 47, pl. 3, figs. 7, 9.

Echinoconchus punctatus (Martin). Chao, 1927, p. 67, pl. 6, figs. 7, 8, 15, 16; Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 103, pl. 18, fig. 120; Dedok and Tschernjak, 1960, p. 53, pl. 1, fig. 6; Pareyn, 1961, p. 197, pl. 23, figs. 1-4; Ding in Yang et al., 1962, p. 51, pl. 19, figs. 1-4; Yang, 1964, p. 81, pl. 4, figs. 5, 6, 9, 10, text-fig. 7; Abramov, 1965, p. 38, pl. 3, fig. 2; Aksenova in Litvinovich et al., 1969, p. 164, pl. 9, figs. 5, 6; pl. 10, fig. 1; Abramov, 1970, p. 117, pl. 9, fig. 4; Alexandrow and Solomina, 1973, p. 93, pl. 22, figs. 1-3; Volgin and Kushnar, 1975, p. 46, pl. 4, fig. 1; Donakova, 1978, p. 208, pl. 1, figs. 5, 6; Nalivkin, 1979, p. 78, pl. 24, figs. 8, 9; Zhang et al., 1983, p. 288, pl. 127, fig. 111; pl. 128, fig. 2; Jin et al., 1985, p. 192, pl. 9, figs. 11, 12; Zhan and Wu, 1987, p. 207, pl. 48, fig. 38; Archbold and Stojanović-Kuzenko, 1995, pl. 62, fig. 10; Wang and Yang, 1998, p. 77, pl. 9, figs. 17, 18.

Productus (Echinoconchus) punctatus (Martin) em. Thomas. Paeckelmann, 1931, p. 152, pl. 15, figs. 7–10.

*Productus (Echinoconchus) punctatus* (Martin). Nalivkin, 1937, p. 64, pl. 9, fig. 5.

Echinoconchus punctatus (Sowerby). Muir-Wood, 1951, p. 102, pl. 4, fig. 2; Muir-Wood and Cooper, 1960, pl. 66, figs. 1, 2;

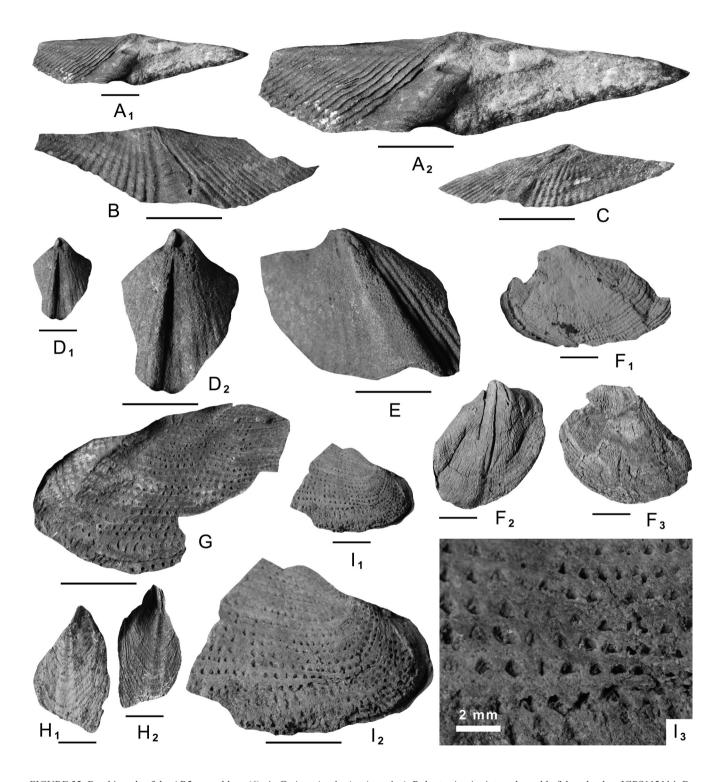


FIGURE 32. Brachiopods of the AR2 assemblage (6). **A–C**, *Acuminothyris triangularis* Roberts; A<sub>1</sub>, A<sub>2</sub>, internal mould of dorsal valve, IGPS112114; B, internal mould of dorsal valve, IGPS112128; C, internal mould of dorsal valve, IGPS112129; **D, E**, *Brachythyris chouteauensis* (Weller); D<sub>1</sub>, D<sub>2</sub>, internal mould of ventral valve, UHR16252; E, internal mould of dorsal valve, UHR16012; **F–I**, *Kitakamithyris hikoroitiensis* Minato; external latex cast of dorsal valve (F<sub>1</sub>), internal mould of ventral valve (F<sub>2</sub>) and internal mould of dorsal valve (F<sub>3</sub>) of conjoined shell, IGPS112107; G, external latex cast of dorsal valve, IGPS112109; external latex cast (H<sub>1</sub>) and external mould (H<sub>2</sub>) of ventral valve, IGPS111727; external mould (I<sub>1</sub>, I<sub>2</sub>) and enlarged concentric rows of biramous spine bases (I<sub>3</sub>) of external mould of dorsal valve, NU-B2257. Scale bars are 1 cm, except for I<sub>3</sub>.

pl. 82, figs. 8–10; pl. 83, figs. 1–4; pl. 88, fig. 11; pl. 125, fig. 5; Winkler Prins, 1968, p. 89, pl. 3, figs. 12–14; Nalivkin and Fotieva, 1973, p. 35, pl. 6, fig. 8; Kalashnikov, 1974, p. 48, pl. 9, figs. 1–3; Martinez Chacon and Legrand-Blain, 1992, p. 110, pl. 3, figs. 15–18; Tazawa, 2017, p. 335, figs. 6.6, 6.7; Tazawa, 2018c, p. 46, figs. 23G, H.

Echinoconchus (Echinoconchus) punctatus (Sowerby). Galitskaya, 1977, p. 62, pl. 16, figs. 1–5; pl. 18, fig. 1, text-fig. 7; Kalashnikov, 1980, p. 34, pl. 5, fig. 1.

Echinoconchus aohanensis Lee et al., 1980, p. 363, pl. 147, figs. 1, 2.

**Material.**—Two specimens from KF159: (1) external and internal moulds of a ventral valve, NU-B2155; and (2) external and internal moulds of a dorsal valve, NU-B2156.

Remarks.—These specimens were described by Tazawa (2017, p. 335, figs. 6.6, 6.7) as Echinoconchus punctatus (Sowerby, 1822). The specimens from Tairagai are referred to E. punctatus (Sowerby, 1822), refigured by Muir-Wood and Cooper (1960, pl. 66, figs. 1, 2; pl. 82, figs. 8–10; pl. 83, figs. 1-4; pl. 88, fig. 11; pl. 125, fig. 5) from the Visean of the UK (Scotland and England) and Belgium, by the large size (length about 62 mm, width about 82 mm in the larger specimen, NU-B2155), regular broad bands on the ventral valve, prominent bilobate cardinal process and elongate smooth adductor scars in the dorsal valve. The smaller dorsal valve specimen may be a young shell. Anomites punctatus, described by Martin (1809), were declared nomenclatorially invalid in 1948 by the International Commission on Zoological Nomenclature, and the species have been referred to subsequent authors, Sowerby, 1822 (Muir-Wood and Cooper, 1960, p. 243). Echinoconchus aohanensis Lee, Gu and Su (1980, p. 363, pl. 147, figs. 1, 2), from the lower Pennsylvanin of Liaoning, northeastern China, is regarded as a junior synonym of the present species. Echinoconchus alternatus (Norwood and Pratten, 1855), redescribed by Weller (1914, p. 138, pl. 17, figs. 1-7), from the Osagean and Meramecian of the Mississippi Valley, USA, differs from *E. punctatus* in having longer hinge.

Occurrence.—OD3 Unit (Yokota).

**Distribution.**—Upper Tournaisian—lower Permian (Asselian): northeastern Japan (Hikoroichi and Yokota in the South Kitakami Belt), northern Russia (Verkhoyansk Range, Taimyr Peninsula and northern Urals), UK (Scotland, England and Wales), Germany, Belgium, Spain, western Russia (Moscow Basin), central Russia (southern Urals), Kyrgyzstan, northwestern China (Xinjiang and Qinghai) and northern China (Shanxi).

Genus ECHINARIA Muir-Wood and Cooper, 1960

Type species.—Productus semipunctatus Shepard, 1838.

Echinaria sp. (Fig. 45C)

Echinaria sp. Tazawa, 2017, p. 336, fig. 7.2.

**Material.**—One specimen from locality KF159, external and internal moulds of a dorsal valve, NU-B2157.

Remarks.—The single dorsal valve specimen from Tairagai was described by Tazawa (2017, p. 336, fig. 7.2) as Echinaria sp. This pecimen can be safely assigned to the genus Echinaria by its external ornament consisting of closely-spaced regular bands with numerous spine bases of two series, larger posterior one and smaller anterior one and elongate adductor scars of dendritic posterior one and smooth anterior one. The Kitakami species is large in size (length more than 60 mm, width more than 55 mm), and closely resembles two species, Echinaria semipunctata (Shepard, 1838), redescribed by Dunbar and Condra (1932, p. 205, pl. 24, fig. 6; pl. 25, figs. 1-3), from the upper Pennsylvanian of Nebraska, and Echinaria rara (Nasikanova in Sarytcheva, 1968, p. 91, pl. 6, figs. 11-16, text-figs. 33-35), from the Bashkirian of eastern Kazakhstan, in size and shape of the dorsal valve, although accurate comparison is difficult owing to ill-preservation of the present material. Echinaria minatoi Tazawa (1981a, p. 54, pl. 4, figs. 3–11), from the lower part of the Nagaiwa Formation (upper Visean-Serpukhovian) of the Hikoroichi area, South Kitakami Belt, is readily distinguished from the Tairagai species by its much smaller dimensions.

Occurrence.—OD3 Unit (Yokota).

**Distribution.**—Upper Visean: northeastern Japan (Yokota in the South Kitakami Belt).

Family WAAGENOCONCHIDAE Muir-Wood and Cooper, 1960

Subfamily PUSTULINAE Waterhouse, 1981 Genus *PUSTULA* Thomas, 1914

**Type species.**—*Producta pustulosa* Phillips, 1836.

Pustula pustulosa (Phillips, 1836) (Fig. 44E, F)

Producta pustulosa Phillips, 1836, p. 216, pl. 7, fig. 15.Productus pustulosus Phillips. Krenkel, 1913, p. 18, 43, pl. 1, fig. 7.

Pustula pustulosa (Phillips). Thomas, 1914, p. 261, pl. 17, figs. 24–28; pl. 18, fig. 1; Muir-Wood and Cooper, 1960, pl. 59, fig. 4; pl. 84, figs. 1–7; pl. 85, figs. 6–10; Nalivkin and Fotieva, 1973, p. 36, pl. 6, figs. 11–13; Kalashnikov, 1974, p. 51, pl. 10, figs. 6–9; pl. 11, figs. 1, 2; pl. 13, figs. 4, 5; pl. 30, fig. 6; Garanj et al., 1975, p. 163, pl. 65, figs. 3, 4; Volgin and Kushnar, 1975, p. 45, pl. 3, figs. 10–12; Galitskaya, 1977, p. 67, pl. 19, figs. 1–5; pl. 20, fig. 1; Zhang et al., 1983, p. 289, pl. 109, fig. 4; Tazawa, 2017, p. 336, figs. 7.3, 7.4; Tazawa, 2018c, p. 47, fig. 30F.

*Productus (Pustula) pustulosus* Phillips emend. Thomas. Paeckelmann, 1931, p. 138, pl. 13, figs. 2, 3.

Pustula cf. pustulosa (Phillips). Mori and Tazawa, 1980,

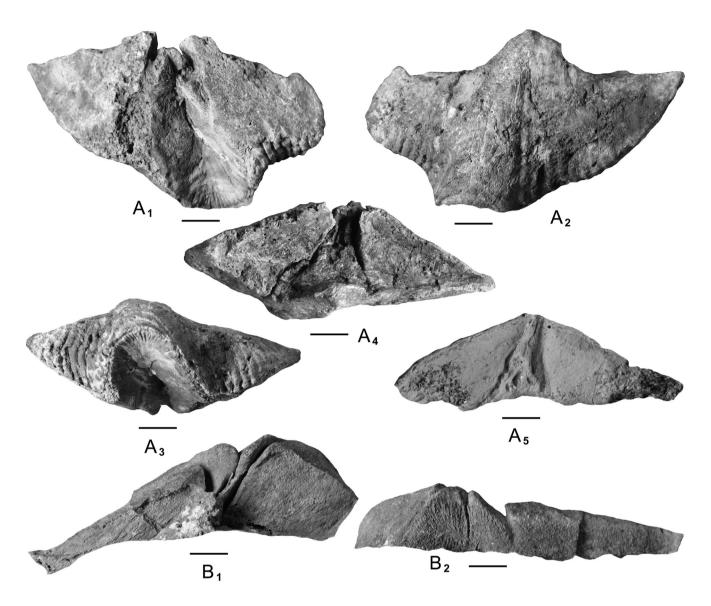


FIGURE 33. Brachiopods of the AR2 assemblage (7). **A, B,** *Syringothyris texta* (Hall); ventral (A1), dorsal (A2), anterior (A3) and posterior (A4) views of internal mould, and external latex cast of ventral interarea (As) of conjoined shell, UHR16925; posterior (B1) and ventral (B2) views of internal mould of ventral valve, IGPS111710. Scale bars are 1 cm.

text-fig. 3.2; Tazawa, 1984b, p. 306, pl. 61, fig. 8.

**Material.**—Two specimens from KF159: (1) external and internal moulds of a ventral valve, NU-B2158; and (2) external and internal moulds of a dorsal valve, NU-B2159.

**Remarks.**—The fragmentary specimens from Tairagai were described by Tazawa (2017, p. 336, figs. 7.3, 7.4) as *Pustula pustulosa* (Phillips, 1836). The Tairagai specimens are referred to *P. pustulosa* (Phillips, 1836), redescribed by Thomas (1914, p. 261, pl. 17, figs. 24–28; pl. 18, fig. 1) from the upper Visean of England, by the large size (length more than 47 mm, width more than 42 mm in the ventral valve specimen, NU-B2158),

subrectangular outline, well-developed ventral sulcus and dorsal fold, and external ornament of both valves consisting of regular concentric bands and numerous, quincunxially arranged elongate spine bases. *Pustula* cf. *pustulosa* (Phillips, 1836), figured by Mori and Tazawa (1980, text-fig. 3.2) and subsequently described by Tazawa (1984b, p. 306, pl. 61, fig. 8) from the upper part of the Hikoroichi Formation of the Hikoroichi area, South Kitakami Belt, is regarded as a synonym of the present species. *Pustula tenuipustulosa* Thomas (1914, p. 288, pl. 20, figs. 10, 11, text-fig. 7) differs from *P. pustulosa* in having smaller spine bases and less-marked bands.

Occurrence.—OD3 Unit (Yokota).

**Distribution.**—Lower Visean–Serpukhovian: northeastern Japan (Hikoroichi and Yokota in the South Kitakami Belt), northern Russia (Pechora Basin), UK (England and northern Ireland), Germany, central Russia (western and southern Urals), Uzbekistan (Fergana), Kyrgyzstan and northwestern China (Xinjiang).

Superfamily LINOPRODUCTOIDEA Stehli, 1954 Family LINOPRODUCTIDAE Stehli, 1954 Subfamily LINOPRODUCTINAE Stehli, 1954 Genus *OVATIA* Muir-Wood and Cooper, 1960

**Type species.**—*Ovatia elongata* Muir-Wood and Cooper, 1960.

Ovatia elongata Muir-Wood and Cooper, 1960 (Fig. 28G)

Ovatia elongata Muir-Wood and Cooper, 1960, p. 312, pl. 114, figs. 1–4, 7, 11, 12: Jin et al., 1979, p. 93, pl. 28, figs. 8, 9, 11; Zhang et al., 1983, p. 297, pl. 108, fig. 9; Zong et al., 2012, p. 423, pl. 1, figs. 41–43; Tazawa and Iryu, 2019, p. 99, fig. 6H.

**Material.**—Two specimens from locality IST1, external moulds of two dorsal valves, IGPS111725, 111726.

Remarks.—These specimens were described by Tazawa and Iryu (2019, p. 99, fig. 6H) as Ovatia elongata Muir-Wood and Cooper, 1960. The specimens from Shimoarisu are referred to O. elongata Muir-Wood and Cooper (1960, p. 312, pl. 114, figs. 1-4, 7, 11, 12), from the lower Fayetteville Formation of Oklahoma, on account of the external characters, the large, elongate shell (length 43 mm, width 24 mm in the larger dorsal valve specimen, IGPS111725) and external ornament of the dorsal valve consisting of numerous fine costellae and irregular rugae, numbering 12-13 costellae in 5 mm at midlength. Ovatia ovata (Hall, 1858), redescribed by Sarytcheva (1937, p. 72, 110, pl. 6, fig. 5) from the upper Visean of the Moscow Basin, western Russia, differs from O. elongata in the smaller and less elongate shell and the finer costellae on the dorsal valve. Ovatia laevicosta (White, 1860), redescribed by Carter (1999, p. 109, figs. 4I-N) from the St. Joe Formation of Oklahoma, differs from O. elongata in having coarser costellae on both ventral and dorsal valves. Ovatia nascens Carter (1988, p. 42, figs. 7.32-7.37), from the Glen Park Formation of Illinois, differs from the present species in having finer costellae.

Occurrence.—AR2 Unit (Shimoarisu).

**Distribution.**—Famennian–upper Visean: northeastern Japan (Shimoarisu in the South Kitakami Belt), USA (Oklahoma) and northwestern China (Xinjiang and Qinghai).

Genus FLUCTUARIA Muir-Wood and Cooper, 1960

**Type species.**—*Productus undatus* Defrance, 1826.

# Fluctuaria undata (Defrance, 1826) (Figs. 38E, 45D)

Productus undatus Defrance, 1826, p. 354; Koninck, 1847, p. 59, pl. 5, fig. 3; Davidson, 1861, p. 161, pl. 34, figs. 10, 11 only; Gröber, 1909, p. 374, pl. 1, fig. 6; Yanishevsky, 1918, p. 45, pl. 5, fig. 10; pl. 8, fig. 12.

Striatifera undata (Defrance). Chao, 1927, p. 114, pl. 9, figs. 7–9.

*Productus (Linoproductus) undatus* Defrance. Paeckelmann, 1931, p. 217, pl. 19, fig. 9; Rotai, 1941, p. 99, pl. 20, fig. 3; Gladchenko, 1955, p. 14, pl. 5, figs. 2, 3.

Productus (Thomasella) undatus Defrance. Nalivkin, 1937, p. 64, pl. 10, fig. 16.

Cancrinella undata (Defrance). Sarytcheva, 1937, p. 82, 111, pl. 7, figs. 1–6, text-figs. 18–20; Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 110, pl. 20, fig. 136; Lapina, 1957, p. 40, pl. 3, figs. 6–8; Yang, 1964, p. 85, pl. 5, fig. 3.

Fluctuaria undata (Defrance). Muir-Wood and Cooper, 1960, pl. 115, figs. 11–20: Sarytcheva in Sarytcheva et al., 1963, p. 229, pl. 37, figs. 6–11, text-figs. 101, 102; Abramov, 1965, p. 43, pl. 4, fig. 12; Nalivkin and Fotieva, 1973, p. 47, pl. 11, figs. 1, 2; Donakova, 1978, p. 212, pl. 1, figs. 11, 12; Martinez Chacon, 1979, p. 223, pl. 25, figs. 8–11; Chen and Shi, 2003, p. 154, pl. 5, figs. 3, 16.

*Productus-Cancrinella-undatus* Defrance. Pareyn, 1961, p. 205, pl. 25, fig. 10.

Fluctuaria cf. undata (Defrance). Tazawa et al., 1981, pl. 1, figs. 11–13; Tazawa, 1981b, p. 72, pl. 5, fig. 7.

**Material.**—Two specimens from localities INS2 and KF210: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, IGPS97659; and (2) external mould of a ventral valve, NU-B2331.

Remarks.—The better preserved specimen (IGPS97659) was previously described by Tazawa (1981b, p. 72, pl. 5, fig. 7) as Fluctuaria cf. undata (Defrance, 1826). But the Nisawa species is referred to Fluctuaria undata (Defrance, 1826), refigured by Muir-Wood and Cooper (1960, pl. 115, figs. 11-20) from the upper Visean of Belgium, in size, shape and external ornament of the ventral and dorsal valves, particularly the small-sized shell, and strongly and somewhat irregularly developed concentric rugae on both valves. Fluctuaria campbelli Roberts (1964, p. 184, pl. 4, figs. 5-13), from the middle Visean of Greenhills, New South Wales, eastern Australia, differs from F. undata in having more numerous finer costellae on the ventral valve. The shells described by Yang (1978, p. 113, pl. 30, fig. 3) as Fluctuaria undata (Defrance, 1826) from the Serphkhovian of Guizhou, southwestern China, are not referred to F. undata in being much transverse outline.

Occurrence.—OD2 Unit (Nisawa) and OD3 Unit (Yahagi).

**Distribution.**—Lower Visean-lower Bashkirian: northeastern Japan (Yahagi and Nisawa in the South Kitakami Belt), central Japan (Hida Gaien Belt), northern Russia (Verkhoyansk Range and northern Urals), UK (Scotland,

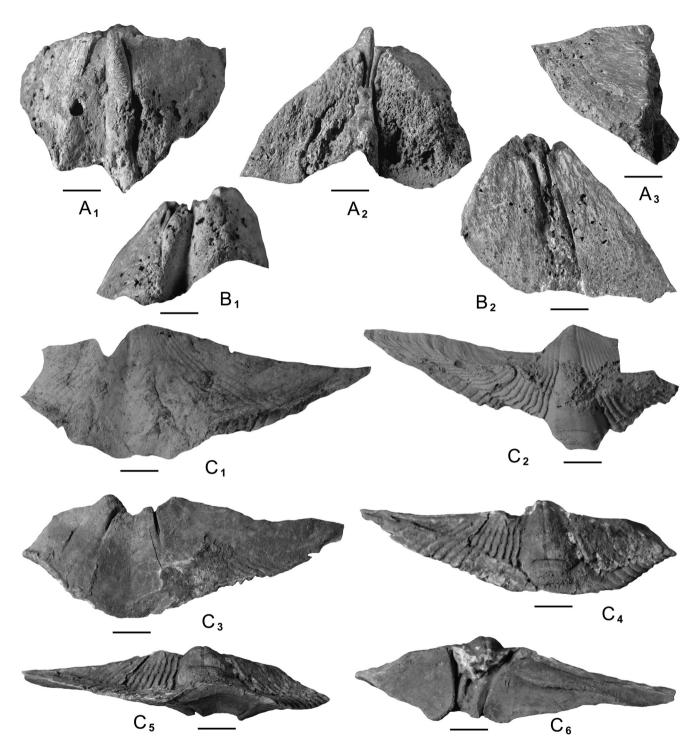


FIGURE 34. Brachiopods of the AR2 assemblage (8). **A, B,** *Syringothyris platypleura* Weller; ventral (A<sub>1</sub>), posterior (A<sub>2</sub>) and lateral (A<sub>3</sub>) views of internal mould of ventral valve, IGPS111711; ventral (B<sub>1</sub>) and posterior (B<sub>2</sub>) views of internal mould of ventral valve, IGPS111712; **C,** *Syringothyris texta* (Hall), ventral (C<sub>1</sub>) and dorsal (C<sub>2</sub>) views of external latex cast, and ventral (C<sub>3</sub>), dorsal (C<sub>4</sub>), anterior (C<sub>5</sub>) and posterior (C<sub>6</sub>) views of internal mould of conjoined shell, IGPS112110. Scale bars are 1 cm.

England, Isle of Man and northern Ireland), Germany, Belgium, Spain, Algeria, western Russia (Moscow Basin), central Russia (southern Urals and Kuznetsk Basin), Kazakhstan, Uzbekistan, Kyrgyzstan and northwestern China (Xinjiang and Gansu).

Subfamily STRIATIFERINAE Muir-Wood and Cooper, 1960 Genus STRIATIFERA Chao, 1927

**Type species.**—*Mytilus striatus* Fischer de Waldheim, 1837.

Striatifera angusta (Yanishevsky, 1910) (Fig. 40A)

Productus striatus (Fischer de Waldheim). Gröber, 1909, p. 369,
pl. 1, fig. 4; Yanishevsky, 1918, p. 29, pl. 1, fig. 8; pl. 6, fig. 8.
Productus striatus var. angusta Yanishevsky, 1910, p. 43, pl. 4, figs. 3, 6.

Striatifera striata var. angusta Yanishevsky. Sarytcheva, 1937, p. 37, pl. 1, fig. 6.

Striatifera angusta (Yanishevsky). Kalashnikov, 1974, p. 80, pl. 23, fig. 4; pl. 26, fig. 4; Galitskaya, 1977, p. 138, pl. 50, figs. 1–6; Jin et al., 1979, p. 93, pl. 28, fig. 3; Zhang et al., 1983, p. 300, pl. 111, fig. 6.

Striatifera cf. striata (Fischer de Waldheim). Tazawa et al., 1981, pl. 1, figs. 14–16.

Striatifera striata (Fischer de Waldheim). Tazawa, 1981b, p. 73, pl. 5, fig. 6.

**Material.**—One specimen from locality INS12, external mould of a conjoined shell, IGPS97660.

**Remarks.**—This specimen was figured by Tazawa et al. (1981, pl. 1, figs. 14–16) as *Striatifera* cf. *striata* (Fischer de Waldheim, 1837), and described by Tazawa (1981b, p. 73, pl. 5, fig. 6) as *Striatifera striata* (Fischer de Waldheim, 1837). But the Nisawa species can be referred to *Striatifera angusta* (Yanishevsky, 1910), redescribed by Kalashnikov (1974, p. 80, pl. 23, fig. 4; pl. 26, fig. 4) from the upper Visean–Serpukhovian of the northern Urals, northern Russia, by the elongate subcyrindrical ventral valve with very small ears. The type species, *Striatifera striata* (Fischer de Waldheim, 1837), redescribed by Sarytcheva (1937, p. 24, 107, pl. 1, figs. 1–5; pl. 2, figs. 1–3, text-figs. 4–7) from the upper Visean–Serpukhovian of the Moscow Basin, western Russia, differs from *S. angusta* in the larger, wider and flattened ventral valve with larger ears.

Occurrence.—OD2 Unit (Nisawa).

**Distribution.**—Upper Visean—Serpukhovian: northeastern Japan (Nisawa in the South Kitakami Belt), northern Russia (northern Urals), western Russia (Moscow Basin), Uzbekistan, Kyrgyzstan and northwestern China (Xinjiang and Qinghai).

Order ORTHOTETIDA Waagen, 1884 Suborder ORTHOTETIDINA Waagen, 1884 Superfamily ORTHOTETOIDEA Waagen, 1884 Family ORTHOTETIDAE Waagen, 1884 Genus ORTHOTETES Fischer de Waldheim, 1829

Type species.—Orthotetes radiata Fischer de Waldheim, 1850.

*Orthotetes keokuk* (Hall, 1858) (Figs. 29I, J, 39H, I)

Orthis keokuk Hall, 1858, p. 640, pl. 19, fig. 5.

Orthotetes keokuk (Hall). Weller, 1914, p. 75, pl. 7, figs. 1–4; Nalivkin, 1937, p. 40, pl. 3, figs. 1, 2; Minato, 1952, p. 151, pl. 11, figs. 1, 2, 4; Simorin, 1956, p. 94, pl. 1, figs. 12, 13; Armstrong, 1962, p. 45, pl. 6, figs. 18–24; Litvinovich, 1962, p. 181, pl. 1, fig. 6; pl. 2, fig. 1; Abramov, 1965, p. 36, pl. 2, fig. 6; pl. 3, fig. 1; Litvinovich in Litvinovich et al., 1969, p. 135, pl. 3, fig. 5; pl. 4, figs. 1–4, text-fig. 40; Abramov, 1970, p. 109, pl. 2, figs. 4, 5; pl. 3, fig. 1; Tazawa, 2018c, p. 52, figs. 25D, 30H.

Derbyia depressa var. transversa Minato, 1952, p. 153, pl. 8, fig. 1.

*Orthotetes* cf. *australis* (Campbell). Tazawa, 1981b, p. 69, pl. 5, fig. 8.

Orthotetes sp. Tazawa, 1984b, p. 305, pl. 61, fig. 11.

Material.—Six specimens from localities INS7, KF179, KF181, YKA20 and YUK1, and from Otsubosawa, Yokota-cho (exact location unknown): (1) external and internal moulds of a ventral valve, IGPS97655; (2) external mould of two ventral valves, IGPS112120, KCG69; (3) external and internal moulds of a dorsal valve, IGPS112162; (4) nxternal mould of a ventral valve, UHR15970: and (5) internal mould of a dorsal valve, IGPS112121.

Remarks.—One of the specimens (IGPS97655) was described by Tazawa (1981b, p. 69, pl. 5, fig. 8) as Orthotetes cf. australis (Campbell, 1957). But all the specimens available are referred to Orthotetes keokuk (Hall, 1858), redescribed by Weller (1914, p. 75, pl. 7, figs. 1-4) from the Keokuk Limestone of the Mississippi Valley, in the large size (length about 75 mm, width about 104 mm in the largest specimen, IGPS112162), transverse outline and external ornament (7–8 costellae in 5 mm at anterior margin) of the dorsal valve, particularly, being widest at about midlength. Orthotetes australis (Campbell, 1957, p. 45, pl. 11, figs. 1-7), from the upper part of the lower Burindi Group of Babbinboon, New South Wales, eastern Australia, differs from O. keokuk in the widest part at or slightly anterior to hinge. The type species, Orthotetes radiata Fischer de Waldheim, 1850, redescribed by Sokolskaya (in Sarytcheva and Sokolskaya, 1952, p. 52, pl. 7, fig. 39) from the Moscovian of the Moscow Basin, western Russia, is distinguished from O. keokuk by the smaller size and less transverse outline. A ventral valve specimen, described by Minato (1952, p. 153, pl. 8, fig. 1) as Derbyia depressa Demanet var. transversa Minato, 1952 from the Jumonji Stage (= AR2 Unit) of the Arisu Formatin, Otsubosawa, Yokota, is identical with the present species in all external and internal characters of the ventral valve.

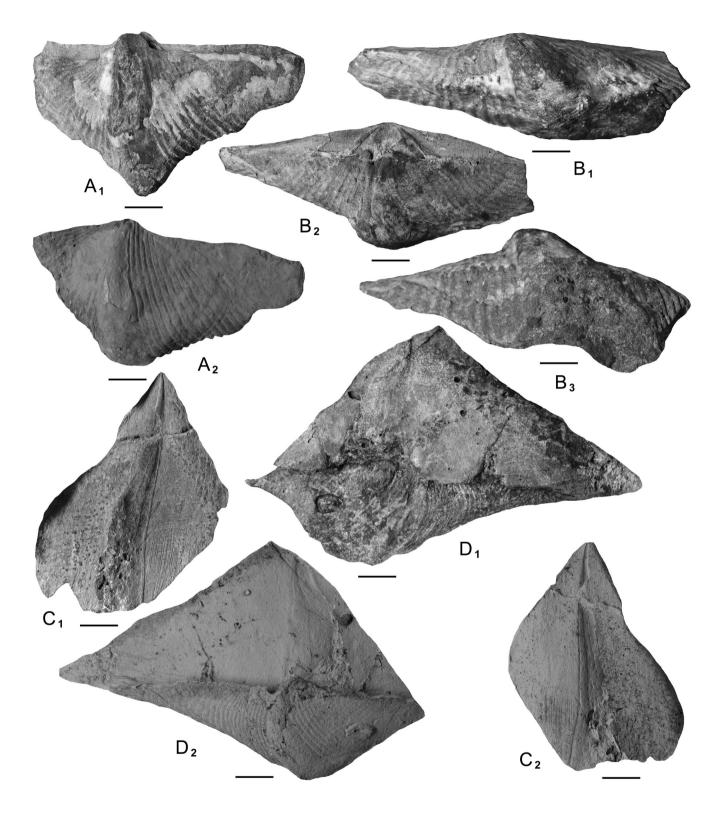


FIGURE 35. Brachiopods of the AR2 assemblage (9). **A, B,** Asyrinxia nipponotrigonalis (Minato); internal mould (A1) and external latex cast (A2) of dorsal valve, UHR16016; dorsal (B1), posterior (B2) and anterior (B3) views of internal mould of conjoined shell, UHR16018; **C, D,** Pseudosyrinx jumonjiensis (Minato); external mould (C1) and external latex cast (C2) of ventral interarea, IGPS111714; external mould (D1) and external latex cast (D2) of conjoined shell, UHR15995. Scale bars are 1 cm.

**Occurrence.**—AR2 Unit (Yokota), OD2 Unit (Nisawa and Shizu) and OD3 Unit (Yahagi).

**Distribution.**—Upper Tournaisian—upper Visean: northeastern Japan (Hikoroichi, Yahagi, Nisawa and Shizu in the South Kitakami Belt), USA (Iowa, Missouri, New Mexico and Arizona), northern Russia (Verkhoyansk Range) and Kazakhstan.

Family PULSIIDAE Cooper and Grant, 1974 Genus *SCHELLWIENELLA* Thomas, 1910

**Type species.**—*Spirifera crenistria* Phillips, 1836.

Schellwienella radialis (Phillips, 1836) (Fig. 45A)

Spirifera radialis Phillips, 1836, p. 220, pl. 11, fig. 5.

Streptorhynchus crenistria var. radialis (Phillips). Davidson, 1861, p. 129, pl. 25, figs. 16–18.

Schuchertella radialis (Phillips). Paeckelmann, 1930, p. 199, pl. 11, figs. 5, 6; pl. 12, figs. 1, 2; pl. 14, fig. 10; Sokolskaya in Sarytcheva and Sokolskaya, 1952, p. 43, pl. 4, fig. 29; Yang, 1964, p. 63, pl. 2, fig. 1; Zhang et al., 1983, p. 275, pl. 106, fig. 8; Tazawa, 2017, p. 338, fig. 7.1.

Schellwienella aspis mut. radialiformis Demanet, 1934, p. 85, pl. 7, figs. 6–12.

Schuchertella aff. radialis (Phillips). Zhang in Yang et al., 1962, p. 23, pl. 2, fig. 1.

Schellwienella radialis (Phillips). Brunton, 1968, p. 42, pl. 6, figs. 13–24, text-figs. 27–35; Nalivkin, 1979, p. 21, pl. 4, fig. 4; Tazawa. 2017, p. 338, fig. 7.1.

**Material.**—One specimen from locality KF159, external and internal moulds of a ventral valve, NU-B2152.

**Remarks.**—This specimen was described by Tazawa (2017, p. 338, fig. 7.1) as Schellwienella radialis (Phillips, 1836). The Tairagai specimen is poorly preserved but can be referred to S. radialis (Phillips, 1836), redescribed by Brunton (1968, p. 42, pl. 6, figs. 13-24, text-figs. 27-35) on the type specimens from the upper Visean of Fermanagh, northern Ireland, by the medium-sized (length about 32 mm, width about 33 mm), flattened ventral valve, with strong divergent dental plates, and the parvicostellate ornament with concentric growth lines forming serrations along crests of the costellae. S. radialis is distinguished from other species of the genus Schellwienella by the strong parvicostellate ornament. Schellwienella izirii Minato (1951, p. 363, pl. 5, fig. 3), from the Hikoroichi Series (= Odaira Formation) of Okuhinotsuchi, South Kitakami Belt, is not assigned to the genus Schellwienella by the presence of median septum in the ventral valve. The Okuhinotsuchi species is identical with Schizophoria resupinata (Martin, 1809) on account of its size, shape, external ornament and internal structure of the ventral valve.

Occurrence.—OD3 Unit (Yokota).

Distribution. — Upper Tournaisian – upper Visean: northeastern

Japan (Yokota in the South Kitakami Belt), UK (Scotland, England and northern Ireland), Germany, Belgium, western Russia (Moscow Basin), central Russia (southern Urals) and northwestern China (Xinjiang and Gansu).

Order ORTHIDA Schuchert and Cooper, 1932 Suborder DALMANELLIDINA Moore, 1952 Superfamily DALMANELLOIDEA Schuchert, 1913 Family RHIPIDOMELLIDAE Schuchert, 1913 Subfamily RHIPIDOMELLINAE Schuchert, 1913 Genus *RHIPIDOMELLA* Oehlert, 1890

Type species.—Terebratula michelini Léveillé, 1835.

Rhipidomella michelini (Léveillé, 1835) (Figs. 29A–F, 39A–F, 45B)

Terebratula michelini Léveillé, 1835, p. 39, pl. 2, figs. 14–17. Orthis michelini (Léveillé). Davidson, 1861, p. 132, pl. 30, figs. 6, 12

Dalmanella michelini (Léveillé). Frech, 1900, p. 201, pl. 16, fig. 15. Rhipidomella michelini (Léveillé). Rotai, 1931, p. 44, pl. 1, fig. 3; Demanet, 1934, p. 37, pl. 2, figs. 1-9; Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 26, pl. 1, fig. 7: Litvinovich, 1962, p. 177, pl. 1, fig. 1; Zang in Yang et al., 1962, p. 19, pl. 1, figs. 1-7; Ustritsky and Tschernjak, 1963, p. 68, pl. 1, figs. 11, 12; Yang, 1964, p. 58, pl. 1, fig. 1; Brunton, 1968, p. 17, pl. 3, figs. 1-25, text-fig. 5; Litvinovich in Litvinovich et al., 1969, p. 127, pl. 1, figs. 9, 10; Bublichenko, 1971, p. 29, pl. 2, figs. 9-12; Alexandrow and Solomina, 1973, p. 87, pl. 21, fig. 1; Kalashnikov, 1974, p. 21, pl. 3, figs. 7–9; Volgin and Kushnar, 1975, p. 21, pl. 1, figs. 1, 2; Lee and Gu, 1976, p. 231, pl. 131, figs. 1-6; Martinez Chacon, 1979, p. 63, pl. 3, figs. 12–15; pl. 4, figs. 1–15, text-figs. 6, 7; Lee et al., 1980, p. 330, pl. 145, fig. 4; Ding and Qi, 1983, p. 250, pl. 88, fig. 13; Zakowa, 1989, p. 115, pl. 3, fig. 5; pl. 7, fig. 7; Harper and Jeffrey, 1996, fig. 3a. Legrand-Blain in Legrand-Blain et al., 1996, p. 180, pl. 28, figs. 21, 22. Jiang, 1997, pl. 1, fig. 3; Bassett and Bryant, 2006, p. 502, pl. 1, figs. 1-4; pl. 6, figs. 11-17; Sun and Baliński, 2008, p. 519, fig. 26; Bahrammanesh et al., 2011, p. 149, fig. 5aa-dd, 7a-e; Tazawa, 2018c, p. 52, figs. 26A-C, 30G; Tazawa and Iryu, 2019, p. 101, figs. 6A, B; Tazawa and Ibaraki, 2019, p. 16, fig. 4B.

Rhipidomella sp. Tazawa and Katayama, 1979, p. 170, pl. 11, figs. 1–7; Mori and Tazawa, 1980, text-figs. 3.4–3.6; Tazawa, 1984b, p. 305, pl. 61, figs. 5–7.

Material.—Twenty-one specimens from localities IST1, IYK1, KF158, KF175, KF179, KF180, KF181, YKA16 and YUK1: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, IGPS112158; (2) internal mould of three conjoined shells, IGPS111721, 111722, KCG67; (3) internal moulds of six ventral valves, IGPS96102, 96116, 96126, 111723, 112100, NU-B2249; (4) external and internal

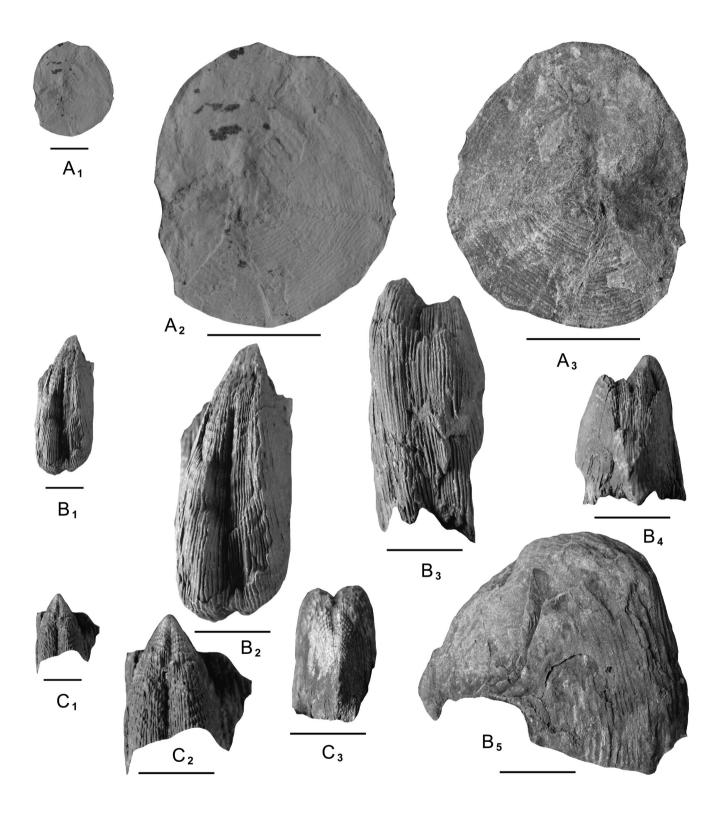


FIGURE 36. Brachiopods of the AR3 assemblage (1). **A,** *Orbiculoidea* sp., external latex cast (A<sub>1</sub>, A<sub>2</sub>) and external mould (A<sub>3</sub>) of ventral valve, NU-B2266; **B, C,** *Marginatia burlingtonensis* (Hall); ventral (B<sub>1</sub>, B<sub>2</sub>), anterior (B<sub>3</sub>), posterior (B<sub>4</sub>) and lateral (B<sub>5</sub>) views of internal mould of ventral valve, NU-B630; ventral (C<sub>1</sub>, C<sub>2</sub>) and posterior (C<sub>3</sub>) views of internal mould of ventral valve, NU-B650. Scale bars are 1 cm.

moulds of two dorsal valves, IGPS112101, KCG68; (5) external moulds of two dorsal valves, IGPS112102, NU-B2256; and (6) internal moulds of seven dorsal valves, IGPS96103, 96111, 96121, 111724, 112103, 112104, NU-B2250.

Remarks.—Some of the specimens were previously described by Tazawa and Katayama (1979, p. 170, pl. 11, figs. 1–7) as *Rhipidomella* sp. But the Odaira species is referred to *Rhipidomella michelini* (Léveillé, 1835), redescribed by Brunton (1968, p. 17, pl. 3, figs. 1–25, text-fig. 5) from the Visean of Fermanagh, northern Ireland, in the small size (length about 24 mm, width about 16 mm in the largest specimen, IGPS96102), ovate outline with short hinge and being widest at slightly anterior to midlength. The other specimens from the Arisu and Odaira formations of Shimoarisu, Yokota and Shizu areas are also referred to the present species. *Rhipidomella altaica* Tolmatchoff (1924, p. 213, 569, pl. 13, figs. 5–7, 9, 10), from the Tournaisian of the Kuznetsk Basin, central Russia, differs from *R. michelini* in having wider hinge and the widest part at midlength of the shell.

**Occurrence.**—AR2 Unit (Shimoarisu and Yokota), OD2 Unit (Yokota and Shizu) and OD3 Unit (Yahagi).

Distribution.—Upper Tournaisian—lower Bashkirian: northeastern Japan (Hikoroichi, Shimoarisu, Yokota, Yahagi and Shizu in the South Kitakami Belt), northern Russia (Taimyr Peninsula and Pechora Basin), UK (England, Wales and northern Ireland), Ireland, Poland, Belgium, France (French Pyrenees), Spain (Cantabrian Mountains), western Russia (Moscow Basin and Donetz Basin), Iran, central Russia (southern Urals), Kazakhstan, Uzbekistan, northwestern China (Xinjiang, Qinghai, Gansu and Ningxia), northern China (Inner Mongolia), northeastern China (Liaoning) and southwestern China (Guizhou and Yunnan).

Rhipidomella kusbassica Beznossova in Sarytcheva et al., 1963 (Fig. 26A)

Rhipidomella michelini (non Léveillé). Tolmatchoff, 1924, p. 212, 569, pl. 13, fig. 4; Nalivkin, 1937, p. 36, pl. 3, figs. 6, 7. Rhipidomela kusbassica Beznossoba in Sarytcheva et al., 1963, p. 74, pl. 2, figs. 9–11; Grechishnikova, 1966, p. 91, pl. 1, figs. 5–10; Zhang et al., 1983, p. 264, pl. 106, fig. 9; Tazawa and Kurita, 2019a, p. 221, fig. 4A; Tazawa in Tazawa et al., 2019, p. 56, fig. 12G, H.

**Material.**—One specimen from locality KAR1, internal mould of a dorsal valve, IGPS111760.

**Remarks.**—This specimen was described by Tazawa and Kurita (2019a, p. 221, fig. 4A) as *Rhipidomella kusbassica* Beznossova in Sarytcheva et al., 1963. The Okuhinotsuchi specimen is poorly preserved but can be referred to *Rhipidomela kusbassica* Beznossoba in Sarytcheva et al. (1963, p. 74, pl. 2, figs. 9–11), from the lower Tournaisian—lower Visean of the Kuznetsk Basin, central Russia, in the small size (length more than 14 mm, width about 15 mm), relatively wide hinge and strong brachiophores diverging anteriorly. *Rhipidomella altaica* 

Tolmatchoff (1924, p. 213, 569, pl. 13, figs. 5–7, 9, 10), from the Tournaisian of the Kuznetsk Basin, is the most similar species having a wide hinge. But *R. altaica* differs from *R. kusbassica* in more transverse outline and in having slightly shorter hinge. The preceding species, *Rhipidomella michelini* (Léveillé), differs from *R. kusbassica* in having much shorter hinge.

Occurrence.—ST3 Unit (Okuhinotsuchi).

**Distribution.**—Lower Tournaisian–lower Visean: northeastern Japan (Nisawa, Okuhinotsuchi and Nagasaka in the South Kitakami Belt), central Russia (Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang).

Superfamily ENTELETOIDEA Waagen, 1884
Family SCHIZOPHORIIDAE Schuchert and LeVene, 1929
Genus SCHIZOPHORIA King, 1850

**Type species.**—Conchyliolithus (Anomites) resupinatus Martin, 1809.

Schizophoria resupinata (Martin, 1809) (Figs. 30F–I, 40B–L, 41I–L)

Conchiliolithus (Anomites) resupinatus Martin, 1809, pl. 49, figs. 13, 14.

*Orthis resupinata* (Martin). Davidson, 1861, p. 130, pl. 29, figs. 1–4; pl. 30, figs. 1–5.

Schizophoria resupinata (Martin). Yanishevsky, 1918, p. 19, pl. 1, figs. 4, 12; pl. 4, fig. 2; pl. 6, fig. 16; Demanet, 1934, p. 45, pl. 3, figs. 1-5, text-fig. 9; Miloradovich, 1935, p. 6, pl. 1, figs. 11, 12; Bond, 1941, p. 289, pl. 21, figs. A-C, text-figs. 33, 34; Minato, 1952, p. 150, pl. 5, fig. 3; pl. 6, fig. 4; Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 29, pl. 2, fig. 12; Parkinson, 1954, p. 368, text-figs. 1, 2; Litvinovich, 1962, p. 178, pl. 1, fig. 2; Besnossova in Sarytcheva et al., 1963, p. 77, pl. 3, figs. 5-8, text-fig. 24; Ustritsky and Tschernjak, 1963, p. 69, pl. 1, figs. 13–16; Yang, 1964, p. 59, pl. 1, figs. 2, 3; Abramov, 1965, p. 35, pl. 2, fig. 3; Brunton, 1968, pl. 2, figs. 1-6; Pocock, 1968, p. 80, pl. 18, fig. 7, text-figs. 13-15; Besnossova et al. in Sarytcheva, 1968, p. 53, pl. 1, figs. 11-13; Lazarev, 1969, pl. 10, figs. 1-5, text-figs. 1, 2; Litvinovichi in Litvinovich et al., 1969, p. 129, pl. 2, fig. 1; Abramov, 1970, p. 107, pl. 1, figs. 5-7; Aisenverg and Poletaev, 1971, pl. 60, fig. 1; Nalivkin and Fotieva, 1973, p. 20, pl. 1, figs. 6–8; Yanagida, 1973, p. 101, pl. 16, figs. 3–9; Kalashnikov, 1974, p. 22, pl. 3, figs. 1–3; Garanj et al., 1975, p. 155, pl. 62, fig. 2; Volgin and Kushnar, 1975, p. 23, pl. 1, figs. 3-5; Litvinovich et al., 1975, p. 52, pl. 16, fig. 7; Lazarev, 1976, pl. 2, figs. 3, 4; pl. 3, figs. 1-5, text-fig. 58, table 11; Lee and Gu, 1976, p. 229, pl. 131, figs. 7, 9-11; Martinez Chacon, 1979, p. 54, pl. 2, figs. 1-15; pl. 3, figs. 1-10, text-figs. 3-5; Minato et al., 1979a, pl. 22, figs. 1, 2; Tazawa and Katayama, 1979, p. 169, pl. 11, figs. 8-14; Kalashnikov, 1980, p. 24, pl. 2, figs. 2, 3; Mori and Tazawa, 1980, text-fig. 3.3; Tazawa, 1981b, p. 67, pl. 5, figs. 3-5; Tazawa

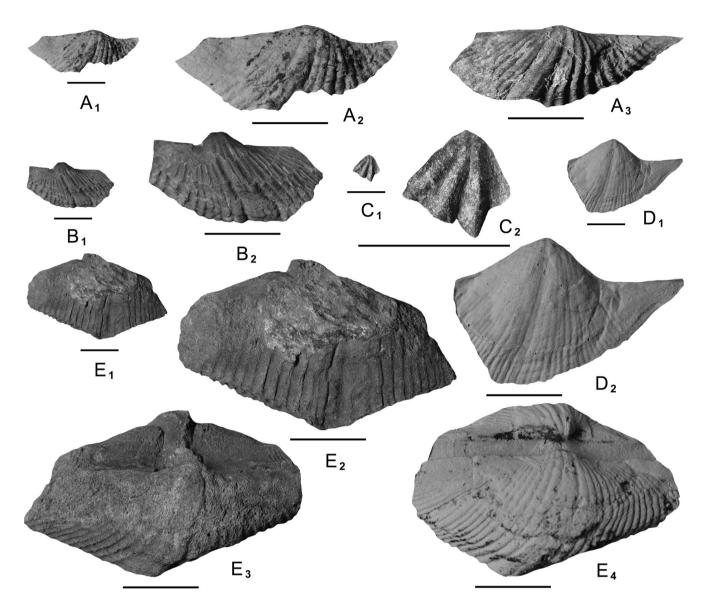


FIGURE 37. Brachiopods of the AR3 assemblage (2). **A, B,** *Brachythyrina* sp.; external latex cast (A<sub>1</sub>, A<sub>2</sub>) and internal mould (A<sub>3</sub>) of dorsal valve, UHR16178; internal mould (B<sub>1</sub>, B<sub>2</sub>) of dorsal valve, UHR15993; **C,** *Punctospirifer* sp., internal mould (C<sub>1</sub>, C<sub>2</sub>) of dorsal valve, NU-B2255; **D, E,** *Unispirifer minnewankensis* (Shimer); external latex cast (D<sub>1</sub>, D<sub>2</sub>) of ventral valve, NU-B2254; ventral (E<sub>1</sub>, E<sub>2</sub>) and dorsal (E<sub>3</sub>) views of internal mould, and dorsal view of external latex cast (E<sub>4</sub>) of conjoined shell, NU-B2253. Scale bars are 1 cm.

et al., 1981, pl. 1, figs. 4–6; Ding and Qi, 1983, p. 245, pl. 88, fig. 7; Zhang et al., 1983, p. 265, pl. 107, figs. 1–3; Tazawa, 1984b, p. 304, pl. 61, fig. 9; Abramov and Grigorjeva, 1986, p. 74, pl. 1, figs. 15–18; Yanai et al., 1988, pl. 1, figs. 9, 10; Zakowa, 1989, p. 103, pl. 1, figs. 1–5; pl. 2, figs. 1–5; pl. 3, figs. 1–4, text-figs. 2–10, table 2; Jiang, 1997, pl. 1, figs. 1, 2; Bassett and Bryant, 2006, p. 504, pl. 6, figs. 1–10; pl. 7, figs. 1–16, text-figs. 5–7; Butts, 2007, p. 55, figs. 5.3–5.10; Ibaraki et al., 2014, p. 73, figs. 4.1, 4.2; Tazawa, 2018c, p. 54, figs. 18A, B, 26G, H, 31A–E; Tazawa and Iryu, 2019, p. 101, fig. 6C, D.

Schellwienella izirii Minato, 1951, p. 363, pl.5, fig. 3. Schellwienella? sp. Minato, 1951, p. 364.

Schizophoria aff. resupinata (Martin). Yanagida, 1962, p. 122, pl. 21, figs. 4–13, text-fig. 22; Hase and Yokoyama, 1975, pl. 16, figs. 6, 7.

Schizophoria (Schizophoria) resupinata (Martin). Sun and Baliński, 2008, p. 521, figs. 27F–L; Bahrammanesh et al., 2011, p. 153, fig. 7f, g.

Material.—Thirty-nine specimens from localities INS2,

INS7, INS9, INS10, INS11, INS13, IST1, KF158, KF177, YKA16, YKA18, YKA20 and YKA21: (1) internal moulds of nine conjoined shells, IGPS111715, 111716, 112138–112144; (2) external and internal moulds of three ventral valves, IGPS112145, 112146, NU-B2251; (3) internal moulds of nineteen ventral valves, IGPS96078, 96080, 96081, 97646–97650, 111717–111720, 112105, 112106, 112147–112150, UHR16142; and (4) internal moulds of eight dorsal valves, IGPS96099, 97651–97654, 112151–112153.

Remarks.—Some of the specimens were described by Tazawa and Katayama (1979, p. 169, pl. 11, figs. 8-14) as Schizophoria resupinta (Martin, 1809). All the specimens avairable are referred to Schizophoria resupinata (Martin, 1809), redescribed by Pocock (1968, p. 80, pl. 18, fig. 7, text-figs. 13-15) from the upper Tournaisian-upper Visean of Belgium and the Britain, in the large size (length more than 40 mm, width about 67 mm in the largest specimen, IGPS112138), transversely subrectangular outline, respinate shell, and the moderately incised and flabellate ventral muscle field. Schizophoria connivens (Phillips, 1836), redescribed by Pocock (1968, p. 64, pl. 18, figs. 1, 2, text-figs. 1-4) from the Tournaisian-Visean of Belgium and the Britain, differs from S. resupinata in the smaller size and in having deeper sulcus and more strongly incised, elliptical muscle field in the ventral valve. Two species, described by Minato (1951) as Schellwienella izirii Minato, 1951 and Schellwienella? sp. from the Hikoroiti Series (= Odaira Formation) of "the 808 m hill", Nisawa, are identical with S. resupinata (Martin) in size, shape, external ornament and internal structure of the ventral valves.

**Occurrence.**—AR2 Unit (Shimoarisu and Yokota) and OD2 Unit (Yokota, Nisawa and Shizu).

Distribution.—Upper Tournaisian—upper Visean: northeastern Japan (Hikoroichi, Shimoarisu, Yokota, Nisawa and Shizu in the South Kitakami Belt), central Japan (Kanto Mountains), southwestern Japan (Akiyoshi Belt), USA (Idaho), northern Russia (Verkhoyansk Range, Taimyr Peninsula, Novaya Zemlya and Pechora Basin), UK (England and Wales), Poland, Belgium, Spain, western Russia (Moscow Basin and Donetz Basin), Iran, central Russia (southern Urals and Kuznetsk Basin), Kazakhstan, Uzbekistan (Fergana), northwestern China (Xinjiang and Shaanxi), northern China (Inner Mongolia) and southwestern China (Guizhou and Yunnan).

Schizophoria pinguis Demanet, 1934 (Figs. 26B, C, 30B–E)

Schizophoria resupinata var. pinguis Demanet, 1934, p. 59, pl. 4, figs. 9–11; Bond, 1941, figs. 33, 34; Pocock, 1968, text-fig. 21.

Schizophoria pinguis Demanet. George and Ponsford, 1938, figs. 8, 9; Tazawa and Iryu, 2019, p. 102, fig. 6E, F; Tazawa and Kurita, 2019a, p. 222, fig. 4B, C.

Shizophoria resupinata pinguis Demanet. Tazawa and Kurita, 1986, p. 167, figs. 2.2, 2.3.

Schizophoria (Schizophoria) resupinata forma pinguis Demanet. Zakowa, 1989, p. 109, pl. 6, figs. 1–10; pl. 7, figs. 1–4, text-figs. 2–9, table 6.

**Material.**—Twelve specimens from localities IST1, KAR1, KF179, KF180 and KF181: (1) external and internal moulds of a dorsal valve, IGPS111729; and (2) internal moulds of three ventral valves, IGPS112084–112086; and (3) internal moulds of eight dorsal valves, IGPS 99006, 99007, 111730–111732, 112087–112089.

Remarks.—Most of the specimens were previously described by Tazawa and Kurita (1986, p. 167, figs. 2.2, 2.3) as Schizophoria resupinata pinguis Demanet, 1934, and by Tazawa and Iryu (2019, p. 102, fig. 6E, F) and Tazawa and Kurita (2019a, p. 222, fig. 4B, C) as Schizophoria pinguis Demanet (1934). The Shimoarisu and Okuhinotsuchi specimens are referred to Schizophoria pinguis Demanet (1934, p. 59, pl. 4, figs. 9-11), from the upper Visean of Visé, Belgium, in the medium to large size (length 48 mm, width 28 mm in the largest specimen, IGPS111729; length 23 mm, width 46 mm in the best preserved specimen, IGPS111730), highly inflated dorsal valve and weakly uniplicate anterior commissure. Schizophoria gibbera (Portlock, 1843), redescribed by Pocock (1968, p. 69, pl. 18, fig. 3, text-figs. 5-7) from the upper Tournaisian-lower Visean of England and Ireland, has also strongly convex dorsal valve, but differs from S. pinguis in having a concentric fold on the dorsal valve. The type species, Schizophoria resupinata (Martin, 1809), is readily distinguished from the present species in having gently convex dorsal valve.

**Occurrence.**—ST3 Unit (Okuhinotsuchi) and AR2 Unit (Shimoarisu and Yokota).

**Distribution.**—Upper Tournaisian—upper Visean: northeastern Japan (Shimoarisu, Yokota and Okuhinotsuchi in the South Kitakami Belt), UK (England), Poland and Belgium.

Schizophoria woodi Bond, 1941 (Fig. 30A)

Schizophoria resupinata var. gibbera (Portlock). Demanet, 1934, p. 55, pl. 4, figs. 1–3 only.

Schizophoria woodi Bond, 1941, p. 299, pl. 22, figs. f, g, text-fig. 37; Pocock, 1968, p. 86, pl. 18, fig. 8, text-figs. 16–19; Lazarev, 1976, pl. 6, fig. 2, text-fig. 64; Tazawa and Iryu, 2019, p. 102, fig. 6G.

Schizophoria (Paraschizophoria) woodi Bond. Zakowa, 1989, p. 113, pl. 8, figs. 1, 2, table 10.

**Material.**—One specimen from IST1, internal mould of a conjoined shell, IGPS111728.

**Remarks.**—The single specimen from Shimoarisu was described by Tazawa and Iryu (2019, p. 102, fig. 6G) as *Schizophoria woodi* Bond, 1941. The Shimoarisu specimen is referred to *Schizophoria woodi* Bond (1941, p. 299, pl. 22, figs. F, G, text-fig. 37), from the upper Visean of Craven, Yorkshire, England, in the small size (length about 33 mm, width about 20

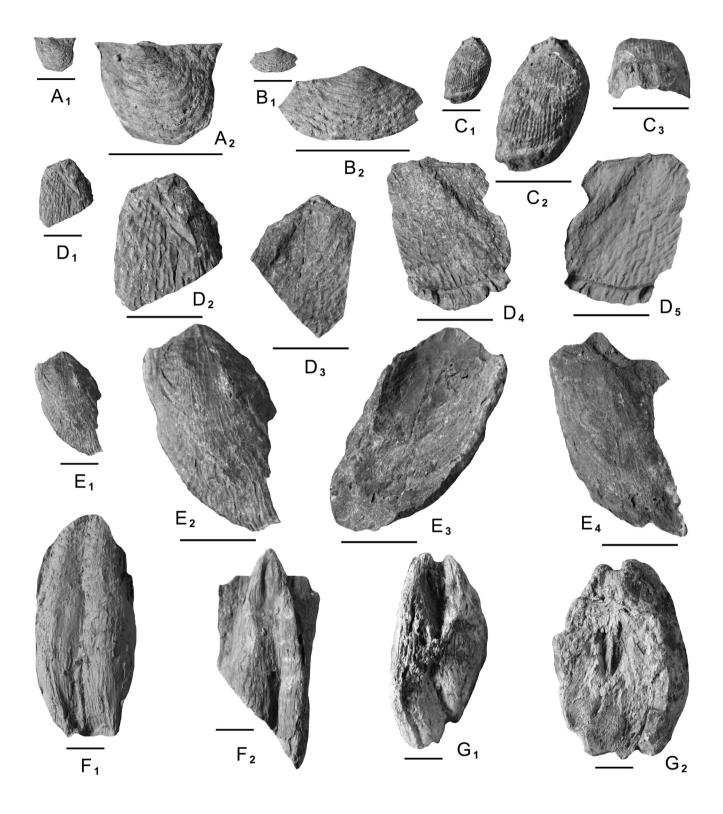


FIGURE 38. Brachiopods of the OD2 assemblage (1). **A, B,** *Absenticosta uldzejtuensis* Suursuren and Lazarev; A, internal mould (A<sub>1</sub>, A<sub>2</sub>) of ventral valve, IGPS112133; B, internal mould (B<sub>1</sub>, B<sub>2</sub>) of dorsal valve, IGPS112134; **C, D,** *Marginicinctus marginicinctus* (Prout); C, ventral (C<sub>1</sub>, C<sub>2</sub>) and anterior (C<sub>3</sub>) views of internal mould of ventral valve, IGPS97657; D, ventral internal mould (D<sub>1</sub>, D<sub>2</sub>), dorsal internal mould (D<sub>3</sub>), dorsal external mould (D<sub>4</sub>) and dorsal external latex cast (D<sub>5</sub>) of conjoined shell, IGPS97656; **E,** *Fluctuaria undata* (Defrance); ventral internal mould (E<sub>1</sub>, E<sub>2</sub>), dorsal internal mould (E<sub>3</sub>) and dorsal external mould (E<sub>4</sub>) of conjoined shell, IGPS97659; **F, G,** *Levitusia elongata* sp. nov.; F, external latex cast (F<sub>1</sub>) and internal mould (F<sub>2</sub>) of ventral valve, IGPS112154; G, ventral (G<sub>1</sub>) and dorsal (G<sub>2</sub>) views of internal mould of conjoined shell, IGPS112155. Scale bars are 1 cm.

mm) and the strongly dorsibiconvex shell, with angular uniplicate anterior commissure. *Schizophoria palliata* Demanet (1934, p. 58, pl. 4, figs. 7, 8), from the upper Tournaisian of Belgium, differs from *S. woodi* in having a rounded anterior commissure.

Occurrence.—AR2 Unit (Shimoarisu).

**Distribution.**—Upper Tournaisian—Serpukhovian: northeastern Japan (Shimoarisu in the South Kitakami Belt), UK (England, Isle of Man and northern Ireland), Poland, Belgium and central Russia (southern Urals).

Schizophoria mayesensis Carter, 1999 (Fig. 26D-F)

Schizophoria mayesensis Carter, 1999, p. 109, figs. 6A-nn, tt, 7; Tazawa and Kurita, 2019a, p. 223, fig. 4D-F.

**Material.**—Three specimens from locality KAR1: (1) internal mould of a ventral valve, IGPS111762; and (2) external and internal moulds of two dorsal valves, IGPS111763, 111764.

Remarks.—These specimens were described by Tazawa and Kurita (2019a, p. 223, fig. 4D–F) as *Schizophoria mayesensis* Carter, 1999. The Okuhinotsuchi specimens can be referred to *Schizophoria mayesensis* Carter (1999, p. 109, figs. 6A–nn, tt, 7), from the St. Joe Formation of Mayes County, northeastern Oklahoma, in being medium size (length 21 mm, width more than 25 mm in the largest specimen, IGPS111763), transversely subelliptical outline with the greatest width at slightly posterior to midlength, and thin-bodied shell with flattened ventral valve and gently convex dorsal valve. *S. mayesensis* resembles *Schizophoria chouteauensis* Weller (1914, p. 163, pl. 23, figs. 6–19), from the Chouteau Limestone of Missouri, but the latter differs from *S. mayesensis* in having less transverse outline and the maximum width at about midlength.

Occurrence.—ST3 Unit (Okuhinotsuchi).

**Distribution.**—Upper Tournaisian: northeastern Japan (Okuhinotsuchi in the South Kitakami Belt) and USA (Oklahoma).

Order RHYNCHONELLIDA Kuhn, 1949 Superfamily RHYNCHOTETRADOIDEA Licharew, 1956 Family TETRACAMERIDAE Licharew, 1956 Genus *ROTAIA* Rzhonsnitskaya, 1956

**Type species.**—*Rhynchonella subtrigona* Meek and Worthen, 1860.

Rotaia hikoroichiensis Tazawa, 2006 (Fig. 41M)

Rotaia sp. Tazawa, 1996, p. 8, fig. 4; Tazawa, 2002, fig. 7.3–7.5.

Rotaia hikoroichiensis Tazawa, 2006, p. 135, fig. 8.1–8.3; Tazawa, 2018c, p. 56, figs. 26E, F, 30I.

**Material.**—One specimen from locality YKA20, external and internal moulds of a ventral valve, IGPS112137.

**Remarks.**—This specimen can be referred to *Rotaia hikoroichiensis* Tazawa, 2006, originally described by Tazawa (2006, p. 135, fig. 8.1–8.3) from the middle part (HK2 Unit) of the Hikoroichi Formation in the Hikoroichi area, South Kitakami Belt, in the large, transverse ventral valve (length about 46 mm, width about 57 mm), with shallow sulcus and ornamented with coarse costae on the valve. Comparison with the other species of *Rotaia* has been discussed by Tazawa (2006, p. 136).

Occurrence.—OD2 Unit (Shizu).

**Distribution.**—Lower–upper Visean: northeastern Japan (Hikoroichi and Shizu in the South Kitakami Belt).

Order ATHYRIDIDA Boucot, Johnson and Staton, 1964
Suborder ATHYRIDINA Boucot, Johnson and Staton, 1964
Superfamily ATHYRIDOIDEA Davidson, 1881
Family ATHYRIDIDAE Davidson, 1881
Subfamily CLEIOTHYRIDININAE Alvarez, Rong and Boucot, 1998

Genus CLEIOTHYRIDINA Buckman, 1906

**Type species.**—Atrypa pectinifera Sowerby, 1840.

Cleiothyridina fimbriata (Phillips, 1836) (Fig. 46H)

Spirifer fimbriata Phillips, 1836, p. 220.

*Terebratula plano-sulcata* (Phillips). de Koninck, 1843, p. 301, pl. 21, figs. 1e, f only.

Athyris roysii Léveillé. Davidson, 1861, p. 84, pl. 18, figs. 8–11 only.

Cleiothyridina fimbriata (Phillips). Brunton and Champion, 1974, p. 829, pl. 109, figs. 22, 23; Brunton, 1980, p. 227, figs. 19–22; Brunton, 1984, p. 53, figs. 53–66; Tazawa, 2017, p. 338, fig. 8.8.

**Material.**—Two specimens from locality KF159, external moulds of two dorsal valves, NU-B2164, 2165.

Remarks.—These specimens were described by Tazawa (2017, p. 338, fig. 8.8) as *Cleiothyridina fimbriata* (Phillips, 1836). The specimens from Tairagai can be referred to *Cleiothyridina fimbriata* (Phillips, 1836), redescribed by Brunton (1980, p. 227, figs. 19–22), from the upper Visean of County Fermanagh, northern Ireland, by the absence of dorsal fold and the external ornament of concentric lamellae with spine-like frilly outgrowths. *Cleiothyridina deroissyi* (Léveillé, 1835), from the Lower Carboniferous (Tournaisian?) of Tournai, Belgium, is readily distinguished from *C. fimbriata* by the presence of distinct ventral sulcus and dorsal fold.

Occurrence.—OD3 Unit (Yokota).

**Distribution.**—Lower—upper Visean: northeastern Japan (Yokota in the South Kitakami Belt), UK (England and northern Ireland) and Belgium.

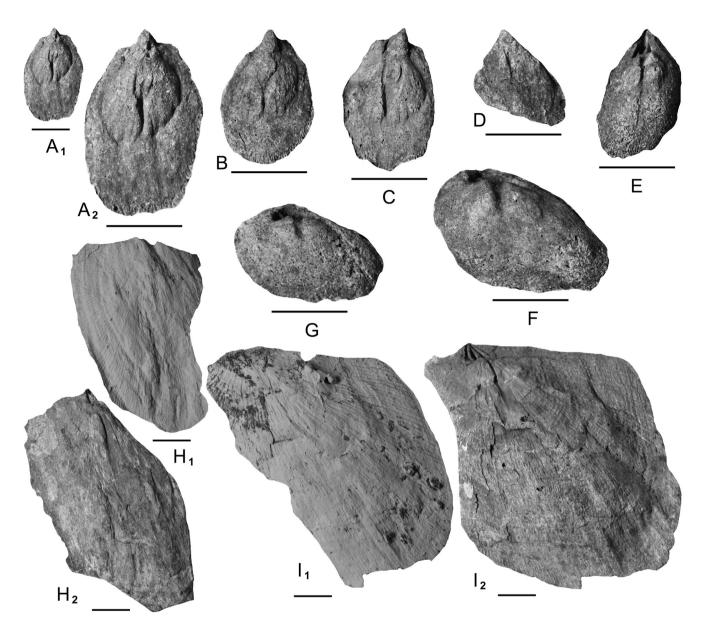


FIGURE 39. Brachiopods of the OD2 assemblage (2). **A–F**, *Rhipidomella michelini* (Léveillé); A–D, internal moulds of ventral valves, IGPS96102 (A<sub>1</sub>, A<sub>2</sub>), IGPS96116 (B), IGPS96126 (C) and NU-B2249 (D); E–G, internal moulds of dorsal valves, IGPS96103 (E), IGPS96111 (F) and IGPS96121 (G); **H**, *Orthotetes keokuk* (Hall); H, external latex cast (H<sub>1</sub>) and internal mould (H<sub>2</sub>) of ventral valve, IGPS97655; I, external latex cast (I<sub>1</sub>) and internal mould (I<sub>2</sub>) of dorsal valve, IGPS11216. Scale bars are 1 cm.

## Cleiothyridina harkeri Carter, 1987 (Fig. 31A)

Cleiothyridina obmaxima (McChesney)? Nelson, 1961, pl. 4, figs. 5, 6; pl. 7, fig. 14; Abramov and Grigorjeva, 1986, pl. 15, figs. 17, 18.

*Cleiothyridina obmaxima* (McChesney). Abramov, 1970, p. 157, pl. 38, figs. 1–3.

*Cleiothyridina harkeri* Carter, 1987, p. 60, pl. 19, figs. 24–27; Tazawa, 2018c, p. 63, fig. 19C; Tazawa and Ibaraki, 2019, p.

19, fig. 5A; Tazawa in Tazawa et al. 2019, p. 58, fig. 12E.

**Material.**—One specimen from locality IYK2, internal mould of a conjoined shell, with external mould of the dorsal valve, NU-B2265.

**Remarks.**—This specimen was described by Tazawa and Ibaraki (2019, p. 19, fig. 5A) as *Cleiothyridina harkeri* Carter, 1987, on the basis of its large, transverse shell (length about 25 mm, width about 36 mm), weakly uniplicate anterior commissure with shallow ventral sulcus and low dorsal fold, and

external ornament consisting of numerous dense growth lamellae. *Cleiothyridina obmaxima* (McChesney), redescribed by Weller (1914, p. 475, pl. 79, figs. 1–11) from the Keokuk and Burlington Formations of the Mississippi Valley, is also a large, transverse *Cleiothyridina*, but the American species differs from *C. harkeri* in having well developed sulcus and fold.

Occurrence.—AR2 Unit (Yokota).

**Distribution.**—Upper Tournaisian-lower Visean: northeastern Japan (Hikoroichi, Yokota and Nagasaka in the South Kitakami Belt), western Canada (Alberta) and northern Russia (Verkhoyansk Range).

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

**Type species.**—Spirifer glaber Sowerby, 1820.

Martinia georgei Tazawa in Tazawa et al., 2019 (Fig. 41A–E)

Martinia aff. glabra (Martin). George, 1927, p. 112, text-figs. 3–11; Demanet, 1938, p. 103, pl. 9, figs. 24–29.

Spirifer (Martinia) glaber Martin. Einor, 1936, p. 40, pl. 7, figs. 4, 5.

*Martinia glabra* (Martin). Yang, 1964, p. 141, pl. 21, figs. 3, 4, text-fig. 32A; Litvinovich in Litvinovich et al., 1969, p. 275, pl. 68, fig. 1; Donakova, 1983, pl. 3, fig. 8.

*Martinia glabra* (Sowerby). Poletaev, 1975, p. 43, pl. 9, figs. 1, 2; Chen and Shi, 2003, p. 168, pl. 11, figs. 1–8, 12–17, 37, 39. *Martinia* sp. Tazawa and Osawa, 1979, p. 775, text-fig. 2.

*Martinia* aff. *glabra* (Sowerby). Tazawa, 1980, p. 366, pl. 42, figs. 6–11; Tazawa et al., 1981, pl. 1, figs. 1–3; Tazawa, 1981b, p. 74, pl. 5, figs. 9–13.

Martinia georgei Tazawa in Tazawa et al., 2019, p. 59, figs. 19E-J.

**Material.**—Twenty-six specimens from localities INS1, INS2, INS3, INS4, INS5, INS6, INS7, INS8, INS10, INS13 and YKA12: (1) external and internal moulds of a ventral valve, IGPS112159; and (2) internal moulds of twenty-five ventral valves, IGPS97662–97684, 112160, 112161.

Remarks.—These specimens were figured by Tazawa et al. (1981, pl. 1, figs. 1–3) and described by Tazawa (1981b, p. 74, pl. 5, figs. 9–13) as *Martinia* aff. *glabra* (Sowerby, 1820). But the specimens from Nisawa are referred to *Martinia georgei* Tazawa (in Tazawa et al., 2019, p. 59, figs. 19E–J), from the upper part of the Karaumedate Formation in the Nagasaka area, South Kitakami Belt, in the medium-sized ventral valve (length 23 mm, width about 44 mm in the largest specimen, IGPS97662), with a shallow sulcus. *Martinia glabra* (Sowerby, 1820), redescribed by Muir-Wood (1951, p. 109, pl. 3, fig. 2)

from the upper Visean of Derbyshire, England, differs from M. georgei in much larger dimensions.

**Occurrence.**—OD2 Unit (Nisawa and Shizu) and OD3 Unit (Nisawa).

**Distribution.**—Lower Visean—Bashkirian: northeastern Japan (Nisawa, Shizu and Nagasaka in the South Kitakami Belt), UK (Wales), Belgium, western Russia (Donetz Basin), central Russia (western and southern Urals), Kazakhstan and northwestern China (Xinjiang).

Superfamily SPIRIFEROIDEA King, 1846 Family SPIRIFERIDAE King, 1846 Subfamily SPIRIFERINAE King, 1846 Genus *SPIRIFER* Sowerby, 1816

**Type species.**—Conchyliolithus (Anomia) striatus Martin, 1793.

Spirifer liangchowensis Chao, 1929 (Figs. 41F–H, 46A–E)

Spirifer liangchowensis Chao, 1929, p. 6, pl. 1, figs. 1–7, text-fig. 1; Yang in Yang et al., 1962, p. 99, pl. 39, fig. 1; Tazawa, 2017, p. 340, figs. 8.1–8.5; Tazawa, 2018c, p. 63, fig. 31G.

Neospirifer liangchowensis (Chao, 1929): Wang et al., 1964, p. 508, pl. 89, figs. 14–16; Ding and Qi, 1983, p. 401, pl. 135, fig. 5.

 $\textit{Spirifer} \; \mathsf{sp.} \; \mathsf{Tazawa}, 1984\mathsf{b}, \mathsf{p.} \; 307, \mathsf{pl.} \; 61, \mathsf{fig.} \; 1.$ 

Material.—Thirteen specimens from localities KF158, KF159 and YKA21: (1) internal moulds of a conjoined shell, with external mould of the ventral valve, IGPS112163; (1) external and internal moulds of a ventral valve, NU-B2166; (2) external mould of a ventral valve, NU-B2167; (3) internal moulds of seven ventral valves, IGPS112164, 112165, NU-B2168, 2169, 2243–2245; (4) external and internal moulds of a dorsal valve, NU-B2170; and (5) internal moulds of two dorsal valves, IGPS112166, NU-B217.

Remarks.—The specimens from Tairagai were described by Tazawa (2017, p. 340, figs. 8.1-8.5) as Spirifer liangchowensis Chao, 1929. The other specimens from Shizu are also referred to S. liangchowensis Chao, 1929, from the Chouniugou Formation of Gansu, northwestern China, on account of the middle-sized, less transverse shell, with deep ventral sulcus and high dorsal fold. Spirifer karagai (Litvinovich, 1962, p. 273, pl. 33, fig. 2), from the upper Visean of central Kazakhstan, resembles S. liangchouensis in size and outline of the shell, but differs from the latter in having shallower ventral sulcus and lower dorsal fold. Spirifer gregeri Weller (1914, p. 359, pl. 55, figs. 1-8), from the lower Burlington Limestone of the Mississippi Valley, differs from S. liangchowensis in its longer shell with shorter hinge. The type species, Spirifer striata (Martin, 1793), from the Visean of Derbyshire, England, is readily distinguished from the present species by the much larger size, transverse outline, and

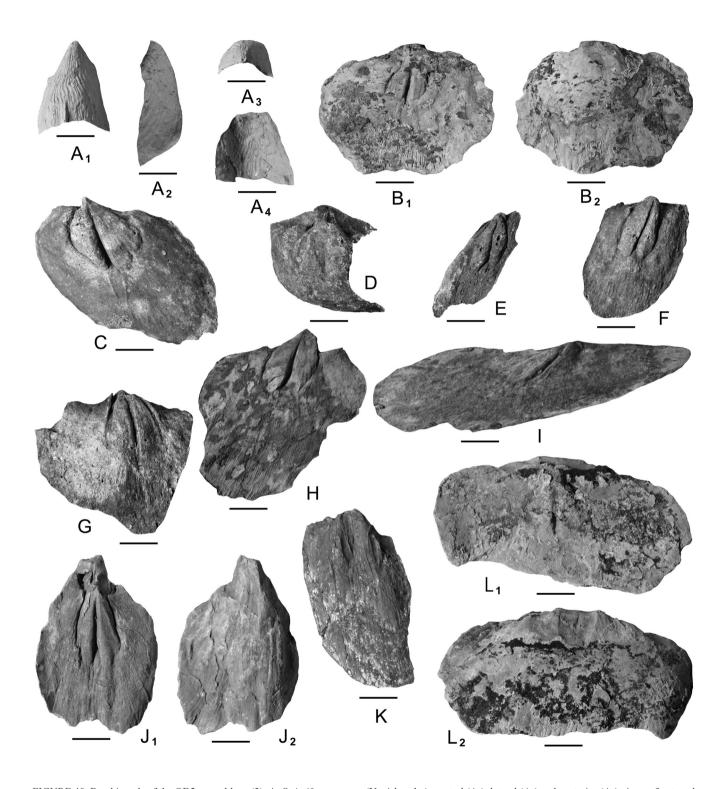


FIGURE 40. Brachiopods of the OD2 assemblage (3). **A**, *Striatifera angusta* (Yanishevsky), ventral (A1), lateral (A2) and posterior (A3) views of external latex cast of ventral valve, and external latex cast of dorsal valve (A4), IGPS97660; **B–L**, *Schizophoria resupinata* (Martin); B, ventral (B1) and dorsal (B2) views of internal mould of conjoined shell, IGPS112139; C, internal mould of ventral valve, IGPS96081; D, internal mould of dorsal valve, IGPS96099; E, internal mould of ventral valve, NU-B2251; F, internal mould of ventral valve, IGPS96080; G, internal mould of ventral valve, UHR16142; H, internal mould of ventral valve, IGPS97646; I, internal mould of ventral valve, IGPS97647; J, ventral (J1) and dorsal (J2) views of internal mould of conjoined shell, IGPS112140; K, internal mould of dorsal valve, IGPS97652; L, ventral (L1) and dorsal (L2) views of internal mould of conjoined shell, IGPS112138. Scale bars are 1 cm.

more acute cardinal extremities.

**Occurrence.**—OD2 Unit (Yokota and Shizu) and OD3 Unit (Yokota).

**Distribution.**—Lower–upper Visean: northeastern Japan (Hikoroichi, Yokota and Shizu in the South Kitakami Belt) and northwestern China (Gansu).

Genus GRANDISPIRIFER Yang, 1959

**Type species.**—Grandispirifer mylkensis Yang, 1959.

Grandispirifer mylkensis Yang, 1959 (Fig. 27B, C)

*Grandispirifer mylkensis* Yang, 1959, p. 113, 118, pl. 1, figs. 1, 2; pl. 2, figs. 1–3; Yang, 1964, p. 121, pl. 16, figs. 4, 5; pl. 17, figs. 1–3, text-figs. 18, 19; Zhang et al., 1983, p. 350, pl. 121, fig. 1; Shi et al., 2016, p. 586, figs. 4, 5A, B; Tazawa and Kurita, 2019b. p. 196. fig. 4.

Spirifer subaequalis Hall. Yang in Yang et al., 1962, p. 99, pl. 39, figs. 2, 3.

**Material.**—Three specimens from localities KAR4, KAR6 and KF181: (1) external and internal moulds of a ventral valve, IGPS111742; and (2) internal moulds of two ventral valves, IGPS111743, 112125.

Remarks.—Two specimens from the middle part of the Arisu Formation (AR2 Unit) of Okuhinotsuchi were described by Tazawa and Kurita (2019b, p. 196. fig. 4) as Grandispirifer mylkensis Yang, 1959. All the specimens from the AR2 Unit of Yokota and Okuhinotsuchin are referred to G. mylkensis Yang, 1959, from the lower Visean of Mt. Borohoro, Xinjiang, northwestern China, in the large, transverse ventral valve (length 36 mm, width 77 mm in the best preserved specimen, IGPS111742) with weakly developed sulcus and rounded cardinal extremities. Shells described by Yang (in Yang et al., 1962, p. 99, pl. 39, figs. 2, 3) as Spirifer subaequalis (Hall) from the Chengqianggou Formation of the southern Qilianshan, Qinghai, northwestern China, are considered to be conspecific with the present species. Grandispirifer gaidamensis Lee, Shi and Chen in Shi et al. (2016, p. 586, figs. 5C, 6, 7), from the upper part of the Huaitoulata Formation of Qinghai, northwestern China, is readily distinguished from G. mylkensis by the strongly transverse outline.

Occurrence.—AR2 Unit (Yokota and Okuhinotsuchi).

**Distribution.**—Upper Tournaisian—lower Visean: northeastern Japan (Yokota and Okuhinotsuchi in the South Kitakami Belt) and northwestern China (Xinjiang and Qinghai).

Suborder SPIRIFERIDINA Waagen, 1883 Superfamily SPIRIFEROIDEA King, 1846 Family SPIRIFERIDAE King, 1846 Subfamily PROSPIRIFERINAE Carter, 1974 Genus *UNISPIRIFER* Campbell, 1957 **Type species.**—Spirifer striatoconvolutus Dun and Benson in Benson, Dun and Browne, 1920.

Unispirifer striatoconvolutus (Dun and Benson in Benson, Dun and Browne, 1920)
(Fig. 31B-D)

*Spirifera striato-convoluta* Dun and Benson in Benson, Dun and Browne, 1920. p. 350, pl. 20, figs. 7, 8.

Unispirifer striatoconvolutus (Dun and Benson). Campbell,
1957, p. 68, pl. 14, figs. 1–9, text-figs. 10–12; Jiang, 1993,
p. 216, pl. 1, figs. 1–14, text-figs. 1, 2; Jiang, 1997, pl. 3, figs.
12–14; pl. 4, fig. 13; Tazawa, 2018c, p. 64, fig. 27D–G.
Tazawa and Iryu, 2019, p. 102, fig. 7A.

*Unispirifer (Unispirifer) striatoconvoluts* (Dun and Benson). Shi et al., 2005, p. 55, figs. 12G–K.

**Material.**—Four specimens from localities IST1 and KF179: (1) internal mould of a conjoined shell, with external mould of the ventral valve, IGPS112094; (2) external moulds of a conjoined shell, IGPS112095; and (3) internal moulds of two ventral valves, IGPS111733, 112096.

Remarks.—One of the specimens (IGPS111733) was described by Tazawa and Iryu (2019, p. 102, fig. 7A) as *Unispirifer striatoconvolutus* (Dun and Benson in Benson, Dun and Browne, 1920), on account of the large, transverse and mucronate ventral valve (length about 26 mm, width about 59 mm), with very shallow sulcus. The other three specimens (IGPS112094–112096) from Yokota are also referred to the present species. *Unispirifer fluctuosus* (Glenister, 1955, p. 68, pl. 7, figs. 1–14; pl. 8, figs. 1–8), from the Moogooree Limestone of the North-West Basin, northwestern Australia, differs from *U. striatoconvolutus* in the smaller size and in having more acute cardinal extremities.

Occurrence.—AR2 Unit (Shimoarisu and Yokota).

**Distribution.**—Upper Tournaisian—upper Visean: northeastern Japan (Hikoroichi, Shimoarisu and Yokota in the South Kitakami Belt), southwestern China (Yunnan), and eastern Australia (New South Wales).

*Unispirifer minnewankensis* (Shimer, 1926) (Fig. 37D, E)

Spirifer centronatus var. minnewankensis Shimer, 1926, p. 52, pl. 1, fig. 8.

*Spirifer minnewankensis* Shimer. Brown, 1952, p. 100, pl. 4, fig. 6; Nelson, 1961, pl. 7, figs. 5, 6.

Spirifer forbesi Norwood and Pratten. Nelson, 1961, pl. 7, figs. 1–4.

Unispirifer sp. Tazawa, 1985, p. 460, figs. 2.1, 2.2.

*Unispirifer minnewankensis* (Shimer). Carter, 1987, p. 75, pl. 23, figs. 1–13, 22–25; Chen and Archbold, 2000, p. 195, figs. 5.7, 5.8.

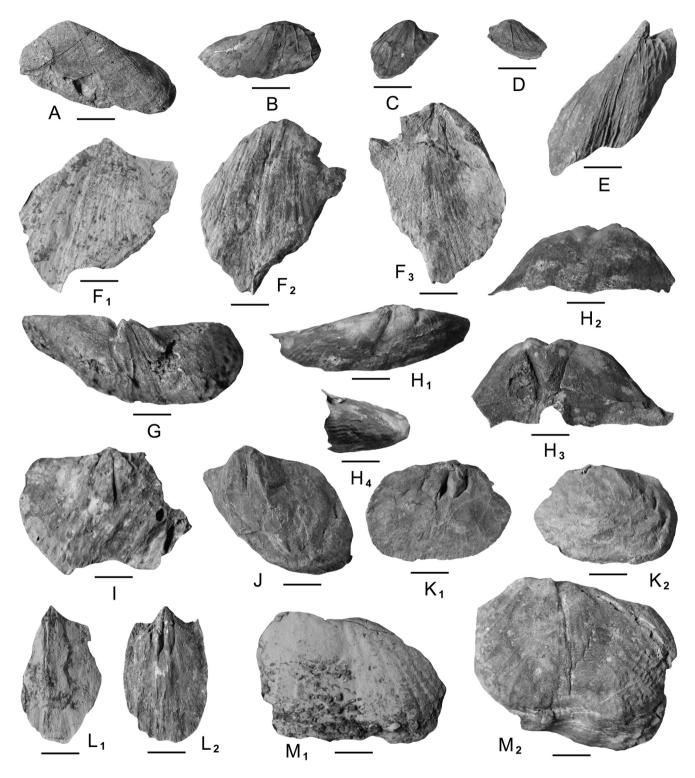


FIGURE 41. Brachiopods of the OD2 assemblage (4). **A–E**, *Martinia georgei* Tazawa; A, internal mould of ventral valve, IGPS97662; B, internal mould of ventral valve, IGPS97663; C, internal mould of ventral valve, IGPS97663; C, internal mould of ventral valve, IGPS97664; D, internal mould of ventral valve, IGPS97668, E, internal mould of ventral valve, IGPS112159; **F–H**, *Spirifer liangchowensis* Chao; external latex cast of ventral valve (F1), and ventral (F2) and dorsal (F3) views of internal mould of conjoined shell, IGPS112163; G, internal mould of ventral valve, NU-B2243; H, ventral (H1), anterior (H2), posterior (H3) and lateral (H4) views of internal mould of conjoined shell, NU-B2244; **I–L**, *Schizophoria resupinata* (Martin); I, internal mould of ventral valve, IGPS112147; J, internal mould of conjoined shell, IGPS112153; K, ventral (K1) and dorsal (K2) views of internal mould of conjoined shell, IGPS112143; L, external latex cast (L1) and internal mould (L2) of ventral valve, IGPS112145; **M**, *Rotaia hikoroichiensis* Tazawa; external latex cast (M1) and internal mould (M2) of ventral valve, IGPS112137. Scale bars are 1 cm.

**Material.**—Two specimens from locality KYT1: (1) external and internal moulds of a conjoined shell, NU-B2253; (2) external mould of a ventral valve, NU-B2254.

Remarks.—These specimens were described by Tazawa (1985, p. 460, figs. 2.1) as *Unispirifer* sp. from the upper part of the Arisu Formation (SR3 Unit) of the Yokota area. But the Yokota specimens are referred to *Unispirifer minnewankensis* (Shimer, 1926, p. 52, pl. 1, fig. 8), from the lower part of the Runde Formation of the Lake Minnewanka region, western Alberta, Canada, in the medium-sized and transverse shell (length about 20 mm, width about 40 mm in the better preserved specimen, NU-B2253), with numerous simple rounded costae on both valves (numbering 5–6 in 5 mm near anterior margin of the ventral valve). *Unispirifer platynotus* (Weller, 1914, p. 317, pl. 39, figs. 1–10), from the Kinderhookian of the Mississippi Valley, differs from *U. minnewankensis* in the smaller size, more alate outline, and in having fewer and stronger costae on both valves.

Occurrence.—AR3 Unit (Yokota).

**Distribution.**—Upper Tournaisian—lower Visean: northeastern Japan (Hikoroichi and Yokota in the South Kitakami Belt), western Canada (Alberta) and northwestern China (Xinjiang).

Unispirifer kozuboensis (Minato, 1952) (Figs. 26G, H, 31F–I)

Spirifer kozuboensis Minato, 1952, p. 155, pl. 5, fig. 7; Minato et al., 1979a, pl. 18, fig. 5.

Unispirifer kozuboensis (Minato). Tazawa and Kurita, 1986, p. 167, fig. 2.1; Tazawa, 2018c, p. 66, fig. 28A–E; Tazawa and Kurita, 2019a, p. 223, fig. 4G, H; Tazawa in Tazawa et al., 2019, p. 64, fig. 15A, B.

Material.—Eight specimens from localities KAR1, KF179, KF181, KYT2 and Otsubosawa (exact location unknown) in Yokota: (1) internal mould of a conjoined shell, with external mould of the ventral valve, UHR15991 (holotype); (2) internal mould of a conjoined shell, IGPS112091; (3) external and internal moulds of a ventral valve, IGPS112126; (4) internal moulds of two ventral valves, IGPS99008, 111761; and (5) internal moulds of three dorsal valves, IGPS112093, 112113, 112127.

Description.—Shell medium in size for genus, wider than long, with greatest width at hinge; cardinal extremities mucronate; length 28 mm, width about 50 mm in the holotype (UHR15991). Ventral valve moderately and unevenly convex in lateral profile, most convex at umbonal region; umbo small, incurved; sulcus narrow and shallow, not clearly demarcated from lateral flanks; ears moderately large, triangular and produced; interarea low, apsacline. External surface of ventral valve ornamented with numerous simple costae, irregular concentric rugae and very fine closely spaced growth lines; costae becoming broad and flat anteriorly and numbering 7–8 in 10 mm on anterior margin. Ventral interior with stout divergent

dental plates. Dorsal interior not well preserved and obscure.

**Remarks.**—This species was originally described by Minato (1952, p. 155, pl. 5, fig. 7) as *Spirifer kozuboensis* Minato, 1952. The Kitakami species is assigned to the genus *Unispirifer*, because of the mucronate cardinal extremities and numerous simple costae on the ventral valve. *Unispirifer tornacensis* (de Koninck, 1883), redescribed by Sartenaer and Plodowski (1996, p. 60, pl. 1, figs. 1–10; pl. 2, figs. 11–19; pl. 3, figs. 27–41; pl. 4, figs. 42–58; pl. 5, figs. 60–73) as *Atylephorus tornacensis* (de Koninck, 1883), from the upper Tournaisian of Belgium, somewhat resembles *U. kozuboensis*; but the Belgian species is distinguished from the latter by the larger dimensions and in having less numerous, stronger costae on the ventral valve.

**Occurrence.**—ST3 Unit (Okuhinotsuchi) and AR2 Unit (Yokota).

**Distribution.**—Upper Tournaisian—lower Visean: northeastern Japan (Hikoroichi, Yokota, Okuhinotsuchi and Nagasaka in the South Kitakami Belt).

*Unispirifer* sp. (Fig. 31E)

Unispirifer sp. Tazawa and Irvu, 2019, p. 104, fig. 7B.

**Material.**—Two specimens from locality IST1, internal moulds of two ventral valves, IGPS111734, 111735.

Remarks.—These specimens were described by Tazawa and Iryu (2019, p. 104, fig. 7B) as *Unispirifer* sp. The specimens from Shimoarisu are safely assigned to the genus *Unispirifer* on the basis of alate cardinal extremities of the ventral valves. The Shimoarisu species resembles *Unispirifer mediocris* (Tolmatchoff, 1924, p. 181, 561, pl. 11, figs. 13, 14), from the Tournaisian of the Kuznetsk Basin, central Russia, in the small size (length 19 mm, width about 25 mm in the larger specimen, IGPS111734) and transverse outline. However, accurate comparison is difficult for the poorly preserved specimens. *Unispirifer kozuboensis* (Minato, 1952, p. 155, pl. 5, fig. 7), from the Do Zone of the Jumonji Stage (= middle part of the Arisu Formation) of the Yokota area, South Kitakami Belt, differs from the present species in the larger size and more transverse outline.

Occurrence.—AR2 Unit (Shimoarisu).

Family CHORISTITIDAE Waterhouse, 1968 Subfamily ANGIOSPIRIFERINAE Legrand-Blain, 1985 Genus *BRACHYTHYRINA* Fredericks, 1929

**Type species.**—Spirifer strangwaysi de Verneuil, 1845.

Brachythyrina sp. (Fig. 37A, B)

*Brachythyrina nagaoi* Minato, 1951, p. 371, pl. 1, figs. 2, 10; pl. 3, fig. 2; pl. 4, fig. 4; Minato et al., 1979a, pl. 20, fig. 3.

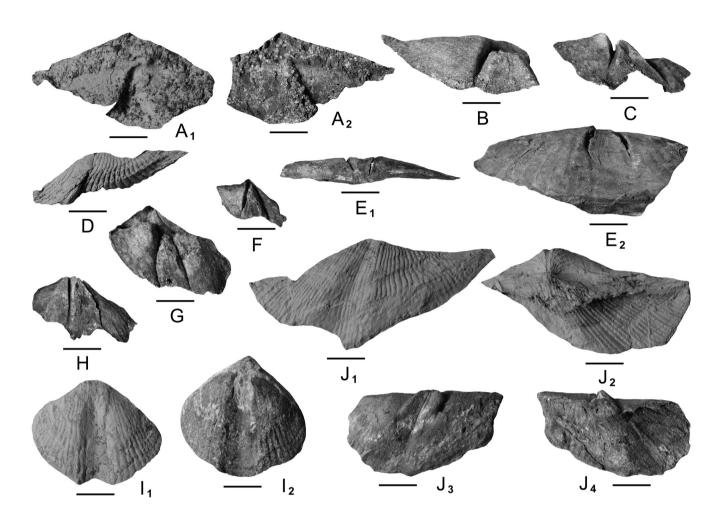


FIGURE 42. Brachiopods of the OD2 assemblage (5). **A–C**, *Syringothyris* sp.; A, external latex cast (A<sub>1</sub>) and external mould (A<sub>2</sub>) of posterior portion of ventral valve, NU-B2246; B, internal mould of ventral valve, NU-B2247; C, internal mould of ventral valve, NU-B2248; **D**, *Asyrinxia nipponotrigonalis* (Minato), external latex cast of dorsal valve, NU-B2264; **E**, *Asyrinxia* sp., posterior (E<sub>1</sub>) and ventral (E<sub>2</sub>) views of internal mould of ventral valve, IGPS97661; **F–H**, *Dimegelasma* sp.; internal moulds of ventral valves, NU-B2241 (F), NU-B2240 (G) and IGPS96136 (H); **I**, *Brachythyris chouteauensis* (Weller), external latx cast (I<sub>1</sub>) and internal mould (I<sub>2</sub>) of ventral valve, UHR16140; **J**, *Imbrexia incertus* (Hall), ventral (J<sub>1</sub>) and dorsal (J<sub>2</sub>) views of external latx cast, and ventral (J<sub>3</sub>) and dorsal (J<sub>4</sub>) views of internal mould of conjoined shell, UHR30191. Scale bars are 1 cm.

**Material.**—Two specimens from locality KF207: (1) external and internal moulds of a dorsal valve, UHR16178; and (2) internal mould of a dorsal valve, UHR15993.

Remarks.—These specimens were described by Minato (1951, p. 371, pl. 1, figs. 2, 10; pl. 3, fig. 2; pl. 4, fig. 4) as *Brachythyrina nagaoi* Minato, 1951, from the E<sub>0</sub> Zone (in the AR3 Unit) of Yokota. However, the specimens from Yokota are inadequate for establishing the new species because of ill preservation. Minato (1951, p. 371) described as follows, "the Japanese form differs from the genotype in having a narrow fold, and simpler median complex of the fold". The dorsal fold is wide and having three or four faint sulci. The Kitakami species somewhat resembles *Brachythyrina lata* Chao (1929), described by Chao (1929, p. 63, pl. 8, figs. 9–14) as *Brachythyrina strangwaysi* var. *lata* Chao,

1929, from the Moscovian–Asselian of Gansu, northwestern China and from Shanxi, northern China, in having medium, transverse dorsal valve (length 14 mm, width 31 mm in the better preserved specimen, UHR16178). The type species, *Spirifer strangwaysi* de Verneuil, 1845, redescribed by Sokolskaya (in Sarytcheva and Sokolskaya, 1952, p. 189, pl. 53, fig. 305) from the Moscovian—Gzhelian of the Moscow Basin, western Russia, differs from the present species in having distinct mucronate cardinal extremities.

Occurrence.—AR3 Unit (Yokota).

Family IMBREXIIDAE Carter, 1992 Genus *IMBREXIA* Nalivkin, 1937 **Type species.**—*Spirifer imbrex* Hall, 1858.

Imbrexia forbesi (Norwood and Pratten, 1855) (Fig. 47A, B)

*Spirifer forbesi* Norwood and Pratten, 1855, p. 73, pl. 9, fig. 3; Weller, 1914, p. 331, pl. 42, figs. 1–3; pl. 43, fig. 16; pl. 83, figs. 1, 2.

Spirifer (Imbrexia) forbesi Norwood and Pratten. Nalivkin, 1937, p. 106, pl. 30, fig. 5.

Imbrexia forbesi (Norwod and Pratten). Armstrong, 1962, p. 52,
pl. 7, figs. 18–21, text-fig. 30; Grechishnikova, 1966, p. 149,
pl. 15, figs. 9, 10; Nalivkin, 1979, p. 138, pl. 49, fig. 6; Lee et al., 1980, p. 410, pl. 154, fig. 14.

**Material.**—Three specimens from locality YUK1: (1) internal mould of a ventral valve, KCG80; (2) external and internal moulds of a dorsal valve, KCG81; and (3) internal mould of a dorsal valve, KCG82.

Remarks.—These specimens are referred to *Imbrexia forbesi* (Norwood and Pratten, 1855), redescribed by Armstrong (1962, p. 52, pl. 7, figs. 18–21, text-fig. 30), from the Keating Formatin (lower Osagean) of New Mexico and Arizona, in the medium, much transverse shell (length about 15 mm, width about 40 mm in the largest specimen, KCG80), with wide ventral sulcus and dorsal fold, and external ornament consisting of numerous simple or bifurcate costae (numbering 5–6 in 5 mm at midlength of dorsal valve) and imbricate growth lamellae. *Imbrexia ussuilensis* Nalivkin (in Garanj et al., 1975, p. 188, pl. 84, figs. 8, 9), from the Kosvinsky Horizon (lower Visean) of the southern Urals, central Russia, differs from *I. forbesi* in the less transverse outline.

Occurrence.—OD 3 Unit (Yahagi).

**Distributin.**—Upper Tournaisian—upper Visean: northeastern Japan (Yahagi in the South Kitakami Belt), USA (New Mexico and Arizona), central Russia (southern Urals), Kazakhstan and northeastern China (Heilongjiang).

Imbrexia incertus (Hall, 1858) (Figs. 42J, 47C)

Spirifer incertus Hall, 1858, p. 602, pl. 13, fig. 3; Weller, 1914, p. 355, pl. 41, figs. 6–14.

Spirifer (Imbrexia) incertus Hall. Nalivkin, 1937, p. 107, pl. 30, fig. 4.

*Imbrexia* cf. *incertus* (Hall). Minato and Kato, 1977, p. 614, pl. 1, figs. 2–11.

Material.—Three specimens from locality YUK1 and north of Mt. Karoyama (exact location unknown), Nisawa: (1) external and internal moulds of a conjoined shell, UHR30191; (2) internal mould of a conjoined shell, with external mould of the dorsal valve KCG83; and (3) external mould of a ventral valve, KCG84.

**Remarks.**—The best preserved specimen (UHR30191), from the Odaira Formation of Nisawa, was described by Minato and Kato (1977, p. 614, pl. 1, figs. 2–11) as *Imbrexia* cf. *incertus* 

(Hall, 1858). But this specimen can be referred to *Imbrexia incertus* (Hall, 1858), redescribed by Weller (1914, p. 355, pl. 41, figs. 6–14.), from the Burlington Limestone of the Mississippi Valley, the USA, in size, shape and external ornament of both valves, particularly in having numerous relatively fine costae (numbering 5 in 5 mm at midlength) on the ventral valve. The type species, *Imbrexia imbrex* (Hall, 1858), redescribed by Carter (1974, p. 687, pl. 1, figs. 1–7; pl. 4, figs. 1–4, text-fig. 3) from the Burlington Limestone of Iowa, differs from *I. incertus* in having coarser costae on the ventral valve.

Occurrence.—OD2 Unit (Nisawa) and OD3 Unit (Yahagi). Distribution.—Upper Tournaisian—upper Visean: northeastern Japan (Yahagi and Nisawa in the South Kitakami Belt), USA (Iowa) and Kazakhstan.

Superfamily PAECKELMANELLOIDEA Ivanova, 1972 Family STROPHOPLEURIDAE Carter, 1974 Subfamily STROPHOPLEURINAE Carter, 1974 Genus *ACUMINOTHYRIS* Roberts, 1963

**Type species.**—Acuminothyris triangularis Roberts, 1963.

Acuminothyris triangularis Roberts, 1963 (Fig. 32A–C)

Acuminothyris triangularis Roberts, 1963, p. 15, pl. 5, figs. 1–8, text-figs. 7, 8; Tazawa, 2018c, p. 68, fig. 28L. "Spirifer" mundulus Rowley. Minato and Kato, 1977, p. 615, pl. 1, fig. 1; Minato et al., 1979a, pl. 14, fig. 2.

**Material.**—Three specimens from localities KF180, KYT3 and KYT4, internal moulds of three dorsal valves, IGPS112114, 112128, 112129.

Remarks.—These specimens can be referred to *Acuminothyris triangularis* Roberts (1963, p. 15, pl. 5, figs. 1–8, text-figs. 7, 8), from the Bingleburra Formation (upper Tournaisian) of Lewinsbrook, New South Wales, eastern Australia, by the large size (length 13 mm, width about 57 mm in the largest specimen, IGPS112114), very transverse outline, moderately broad simple fold, numerous costae on lateral slopes, and fine numerous concentric lamellae on anterior portion of fold. A single ventral valve specimen, described by Minato and Kato (1977, p. 615, pl. 1, fig. 1) as "*Spirifer*" *mundulus* Rowley (1893) from the lower part of the Hikoroichi Formation in the Hikoroichi area, is identical with the present species, although the Hikoroichi specimen is smaller in size.

Occurrence.—AR2 Unit (Yokota).

**Distribution.**—Upper Tournaisian—lower Visean: northeastern Japan (Hikoroichi and Yokota in the South Kitakami Belt) and eastern Australia (New South Wales)

Superfamily BRACHYTHYRIDOIDEA Fredericks, 1924 Family BRACHYTHYRIDIDAE Fredericks, 1924 Genus *BRACHYTHYRIS* M'Coy, 1844

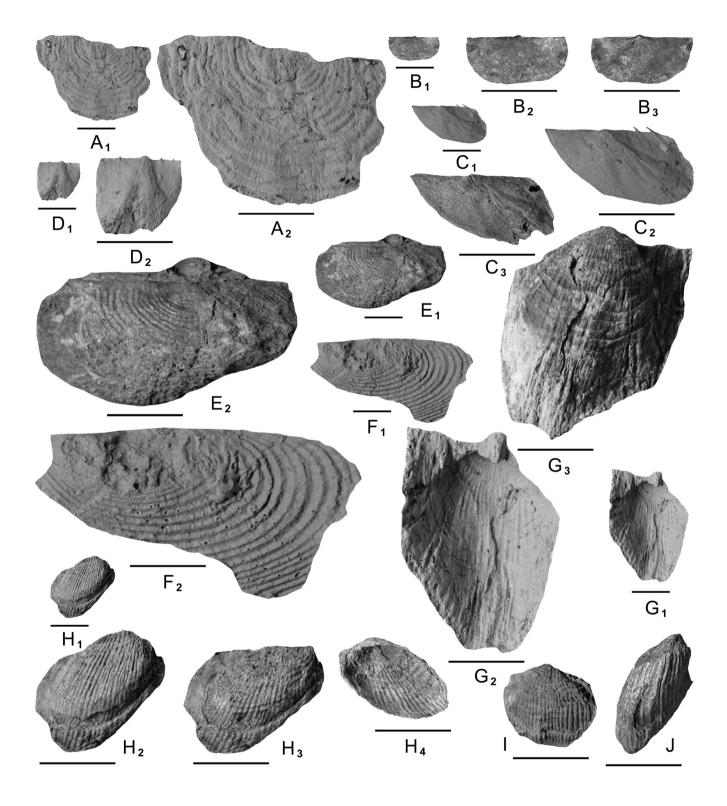


FIGURE 43. Brachiopods of the OD3 assemblage (1). **A,** *Leptagonia analoga* (Phillips), external latex cast (A<sub>1</sub>, A<sub>2</sub>) of ventral valve, NU-B2154; **B, C,** *Rugosochonetes extensus* (Chao); B, external mould (B<sub>1</sub>, B<sub>2</sub>) and internal mould (B<sub>3</sub>) of dorsal valve, NU-B2172; C, external latex cast (C<sub>1</sub>, C<sub>2</sub>) and internal mould (C<sub>3</sub>) of ventral valve, KCG76; **D,** *Rugosochonetes* sp.; external latex cast (D<sub>1</sub>, D<sub>2</sub>) of ventral valve, KCG78; **E,** *Plicatifera pseudoplicatilis* (Muir-Wood); external mould (E<sub>1</sub>, E<sub>2</sub>) of dorsal valve, KCG70; **F,** *Plicatifera plicatilis* (Sowerby); external latex cast (F<sub>1</sub>, F<sub>2</sub>) of ventral valve, KCG65; **G,** *Argentiproductus* sp.; external latex cast (G<sub>1</sub>, G<sub>2</sub>) and external mould (G<sub>3</sub>) of dorsal valve, KCG63; **H–J,** *Alitaria konincki* (Muir-Wood and Cooper); H, ventral (H<sub>1</sub>, H<sub>2</sub>) and dorsal (H<sub>3</sub>) views of internal mould, and dorsal external mould (H<sub>4</sub>) of conjoined shell, KCG71; I, internal mould of ventral valve, KCG73; J, internal mould of ventral valve, KCG72. Scale bars are 1 cm.

**Type species.**—*Spirifera ovalis* Phillips, 1836.

Brachythyris chouteauensis (Weller, 1909) (Figs. 32D, E, 42I, 47D)

Spirifer chouteauensis Weller, 1909, p. 305, pl. 13, fig. 11. Brachythyris chouteauensis (Weller). Weller, 1914, p. 373, pl. 57, figs. 4–11; Branson, 1938, p. 65, pl. 6, figs. 1–4; Sokolskaya in Sarytcheva and Sokolskaya, 1952, p. 193, pl. 54, fig. 312; Carter, 1967, p. 394, pl. 39, figs. 1–9, text-figs. 37, 38; Bublichenko, 1976, p. 123, pl. 14, figs. 1–5; Carter, 1987, p. 82, pl. 26, figs. 7, 8; Liu, 1988, p. 367, pl. 2, fig. 11; Carter, 1999, p. 129, figs. 18M–X.

Sirifer ovalis Phillips. Tolmatchoff, 1924, p. 186, 562, pl. 11, figs. 17, 18.

Brachythyris? sp. Minato, 1951, p. 368, pl. 5, fig. 9.

Brachythyris aff. pinguis (Sowerby). Minato, 1951, p. 369, pl. 1, figs. 14, 15; pl. 3, fig. 8; Minato et al., 1979a, pl. 21, figs. 9, 10.
Brachythyris krapivnensis Beznossova, 1959, p. 123, pl. 10, fig. 6; pl. 11, fig. 14, text-figs. 54, 55; Besnssova in Sarytcheva et al., 1963, p. 297, pl. 57, fig. 4.

Brachythyris sp. Minato et al, 1979a, pl. 17, fig. 9.

Material.—Seven specimens from localities YUK1, 808 m hill in Nisawa and Otsubosawa in Yokota (exact location unknown): (1) internal mould of a conjoined shell, KCG74; (2) external and internal moulds of a ventral valve, UHR16140; (3) internal moulds of three ventral valves, UHR16011, 16250, 16252; (4) external and internal moulds of a dorsal valve, KCG75; and (5) internal mould of a dorsal valve, UHR16012.

**Remarks.**—Most of the specimens, except for two specimens (KCG74, 75) from the uppermost part of the Odaira Formatin in Yahagi, were described by Minato (1951, p. 368-369) as Brachythyris? sp. and Brachythyris aff. pinguis (Sowerby). However, all the specimens are referred to Brachythyris chouteauensis (Weller, 1909), redescribed by Carter (1967, p. 394, pl. 39, figs. 1-9, text-figs. 37, 38) from the Chappel Limestone of Texas, in the medium size (length 26 mm, width 34 mm in the largest specimen, UHR16140), rounded outline and in having one or two pairs of weak costae in the ventral sulcus and a distinct median groove in the dorsal fold. Brachythyris suborbicularis (Hall, 1858), redescribed by Weller (1914, p. 374, pl. 61, figs. 1-8; pl. 62, figs. 1-12) from the Burlington and Keokuk limestones of Iowa, Missouri and Indiana in the USA, differs from B. chouteauensis in the larger dimensions. Brachythyris pinguis (Sowerby, 1820), redescribed by George (1927, p. 108, text-fig. 1) from the upper Visean of Gower, South Wales, is readily distinguished from the present species by the much larger and more transverse shell with broader costae on lateral flanks of both valves.

**Occurrence.**—AR2 Unit (Yokota), OD2 Unit (Nisawa) and OD3 Unit (Yahagi).

**Distribution.**—Lower Tournaisian—upper Visean: northeastern Japan (Yokota, Yahagi and Nisawa in the South Kitakami Belt), USA (Missouri, Oklahoma and Texas), Canada (Alberta),

western Russia (Moscow Basin), central Russia (Kuznetsk Basin), Kazakhstan and northeastern China (Jilin).

Suborder DELTHYRIDINA Ivanova, 1972 Superfamily RETICULARIOIDEA Waagen, 1883 Family ELYTHIDAE Fredericks, 1924 Subfamily ELYTHINAE Fredericks, 1924 Genus *KITAKAMITHYRIS* Minato, 1951

**Type species.**—Torynifer (Kitakamithyris) tyoanjiensis Minato, 1951.

Kitakamithyris hikoroitiensis Minato, 1951 (Fig. 32F–I)

*Torynifer (Kitakamithyris) hikoroitiensis* Minato, 1951, p. 375, pl. 1, fig. 1.

Kitakamithyris hikoroitiensis Minato. Minato, 1952, p. 171, pl. 7, fig. 3; pl. 8, fig. 6; Minato et al., 1979a, pl. 16, fig. 1; Tazawa, 2018c, p. 72, figs. 20B, C, 21B, 29A, B; Tazawa and Iryu, 2019, p. 104, figs. 7C, 8; Tazawa and Ibaraki, 2019, p. 20, fig. 5C. Kitakamithyris semicircularis Minato. Minato, 1952, p. 171, pl. 7, fig. 6; pl. 8, fig. 5; pl. 10, fig. 3; Minato et al., 1979a, pl. 15, fig. 1.

**Material.**— Five specimens from localities IST1, IYK1 and KF179: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, IGPS112107; (2) external and internal moulds of a ventral valve, IGPS112108; (3) external mould of a ventral valve, IGPS111727; and (4) external mould of two dorsal valves, IGPS112109, NU-B2257.

Remarks.—Two specimens, a ventral valve specimen (IGPS111727) from Shimoarisu and a dorsal valve specimen (NU-B2257) from Yokota, were described by Tazawa and Iryu (2019, p. 104, figs. 7C, 8) and by Tazawa and Ibaraki (2019, p. 20, fig. 5C), as Kitakamithyris hikoroitiensis Minato, 1951. The other three specimens (IGPS112107-112109) from Yokota are also referred to Kitakamithyris hikoroitiensis Minato (1951, p. 375, pl. 1, fig. 1), originally described from the lower part of the Hikoroiti Series (= Choanji Formation of Tazawa and Niikawa, 2018) of Tyoanji (Choanji), South Kitakami Belt, on account of the relatively large and sporadically arranged spine bases (numbering 5-6 in 5 mm at about midlength) on both ventral and dorsal vaves. Kitakamithyris semicircularis Minato (1952, p. 171, pl. 7, fig. 6; pl. 8, fig. 5; pl. 10, fig. 3), from the Choanji, Hikoroichi and Arisu Formations of the South Kitakami Belt, is deemed to be a junior synonym of K. hikoroitiensis. The type species, Kitakamithyris tyoanjiensis Minato (1951, p. 374, pl. 1, fig. 3; pl. 4, fig. 7), from the Choanji Formation (Upper Devonian) of Choanji is readily distinguished from K. hikoroitiensis by the much smaller and tightly arranged spine bases on the ventral valve.

Occurrence.—AR2 Unit (Shimoarisu and Yokota).

**Distribution.**—Upper Devonian (upper Famennian)—lower Visean: northeastern Japan (Choanji, Hikoroichi, Shimoarisu

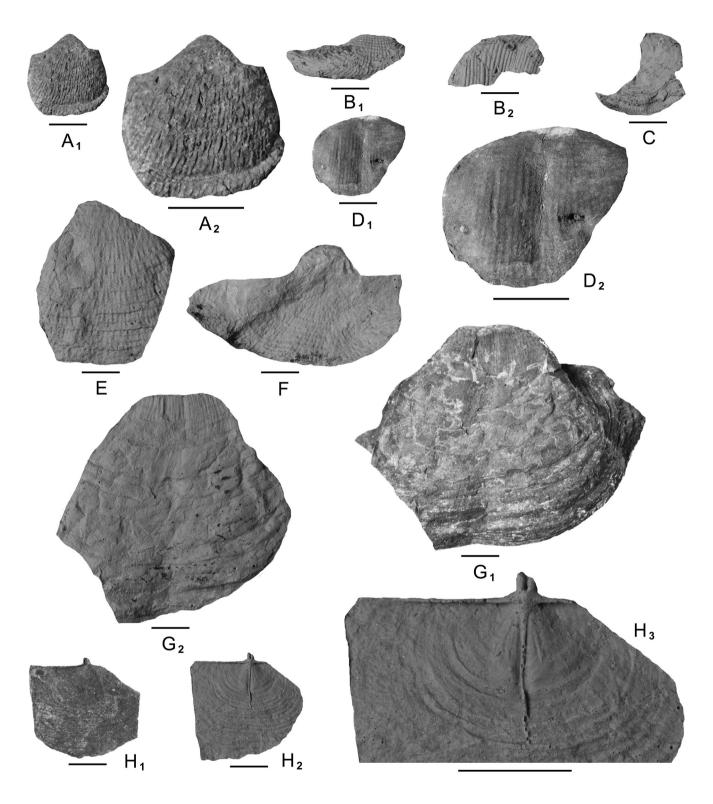


FIGURE 44. Brachiopods of the OD3 assemblage (2). **A,** *Marginicinctus marginicinctus* (Prout), internal mould (A<sub>1</sub>, A<sub>2</sub>) of ventral valve, NU-B2330; **B- D,** *Marginatia burlingtonensis* (Hall); B, ventral (B<sub>1</sub>) and anterior (B<sub>2</sub>) views of external latex cast of ventral valve, NU-B2160; C, external latex cast of dorsal valve, NU-B2162; D, anterior view (D<sub>1</sub>, D<sub>2</sub>) of internal mould of ventral valve, NU-B2161; **E, F,** *Pustula pustulosa* (Phillips); E, external latex cast of ventral valve, NU-B2158; F, external latex cast of dorsal valve, NU-B2159; **G, H,** *Echinoconchus punctatus* (Sowerby); G, internal mould (G<sub>1</sub>) and external latex cast (G<sub>2</sub>) of ventral valve, NU-B2155; H, external mould (H<sub>1</sub>) and internal latex cast (H<sub>2</sub>, H<sub>3</sub>) of dorsal valve, NU-B2156. Scale bars are 1 cm.

and Yokota in the South Kitakami Belt).

*Kitakamithyris* sp. (Figs. 46G, 47E).

*Kitakamithyris* sp. Tazawa, 1979, p. 11, fig. 11.4; Tazawa, 2017, p. 340, fig. 8.7.

**Material.**—Two specimens from locality KF159 and YUK1: (1) external and internal moulds of a ventral valve, KCG79; and (2) internal mould of a ventral valve, NU-B2153.

Remarks.—One of the specimens (NU-B2153) was described by Tazawa (2017, p. 340, fig. 8.7) as *Kitakamithyris* sp. The fragmentarily preserved specimen from Tairagai can be assigned to the genus *Kitakamithyris* by its medium (length about 18 mm, width about 32 mm), subelliptical and gently convex ventral valve, ornamented with numerous radiating grooves on the internal surface, and the presence of a long median septum and a pair of divergent adminicula. The another specimen (KCG79) from Yukisawa in the Yahagi area, also can be assigned to the genus *Kitakamithyris* by the presence of numerous concentric rows of biramous spine bases (numbering 9–10 spine bases in 5 mm at midlength) on the ventral valve. These specimens may be a new species of *Kitakamithyris*, but the poorly preserved specimens preclude that determination.

Occurrence.—OD3 Unit (Yokota and Yahagi).

Subfamily TORYNIFERINAE Carter in Carter et al., 1994 Genus TORYNIFER Hall and Clarke, 1894

**Type species.**—*Spirifer pseudolineatus* Hall, 1858.

Torynifer asiatica Beznossova in Beznossova et al., 1962 (Fig. 47F)

Reticularia lineata Martin. Tolmatchoff, 1924, p. 191, 563, pl. 12, figs. 1–3, 5.

Reticularia sinuata Tolmatchoff, 1924, p. 194, 564, pl. 12, figs. 4, 7.
Reticularia pseudolineata Hall. Nalivkin, 1937, p. 115, pl. 2, figs. 5, 6; pl. 33, fig. 6; Rotai, 1941, p. 114, pl. 28, figs. 2–4; Simorin, 1956, p. 198, pl. 17, figs. 10, 11.

Torynifer pseudolineatus asiaticus Beznossova in Beznossova et al., 1962, p. 176, pl. C-23, figs. 4–5; Beznossova in Sarytcheva et al., 1963, p. 303, pl. 58, figs. 1–6, text-figs. 133–135; Kotlyar and Popeko, 1967, p. 173, pl. 48, figs. 3–6; Plodowski, 1970, p. 106, pl. 8, fig. 2; Yang and Fan, 1983, p. 279, pl. 4, fig. 17; Zhang et al., 1983, p. 368, pl. 124, fig. 7.

*Torynifer pseudolineata* (Hall). Litvinovich in Litvinovich et al., 1969, p. 270, pl. 66, figs. 7, 8.

*Torynifer asiatica* Beznossova. Pavlova, 1969, p. 63, pl. 4, figs. 1–6; pl. 11, figs. 6, 7; pl. 13, fig. 3, text-figs. 37–39; Tazawa, 2018c, p. 72, figs. 32A, B.

**Material.**—One specimen from locality KF210, external and internal moulds of a ventral valve, NU-B2332.

Remarks.—This specimen is referred to *Torynifer asiatica* Beznossova in Beznossova et al. (1962, p. 176, pl. C-23, figs. 4–5), from the upper Tournaisian of the Kuznetsk Basin, central Russia, on account of the external ornament of the ventral valve consisting of slightly irregular concentric lamellae bearing a row of fine biramous spine bases (numbering 7 in 5 mm at about midlength) and the long thin median septum in the ventral valve. The type species, *Torynifer pseudolineata* (Hall, 1858), redescribed by Weller (1914, p. 429, pl. 74, figs. 1–11; pl. 75, fig. 20) from the Keokuk Limestone of the Mississippi Valley, differs from *T. asiatica* in having more prominent ventral sulcus.

Occurrence.—OD3 Unit (Yahagi).

**Distribution.**—Lower Tournaisian—Serpukhovian: northeastern Japan (Hikoroichi and Yahagi in the South Kitakami Belt), Afghanistan, central Russia (Kuznetsk Basin and Transbaykal), Kazakhstan and northwestern China (Xinjiang).

Order SPIRIFERINIDA Ivanova, 1972 Suborder SPIRIFERINIDINA Ivanova, 1972 Superfamily SYRINGOTHYRIDOIDEA Fredericks, 1926 Family SYRINGOTHYRIDIDAE Fredericks, 1926 Subfamily SYRINGOTHYRIDINAE Fredericks, 1926 Genus *SYRINGOTHYRIS* Winchell, 1863

**Type species.**—Syringothyris typa Winchell, 1863.

Syringothyris texta (Hall, 1857) (Figs. 33A, B, 34C)

Spirifer textus Hall, 1857, p. 169.

*Syringothyris textus* (Hall). Weller, 1914, p. 399, pl. 69, figs. 6–9; pl. 70, figs. 1–4; pl. 71, figs. 1, 2.

Syringothyris transversa Minato, 1951, p. 377, pl. 5, fig. 1;
Minato, 1952, p. 167, pl. 11, fig. 5 only; Minato et al., 1979a,
pl. 21, fig. 11; Tazawa, 2002, fig. 7.6; Tazawa, 2006, p. 134,
figs. 7.1, 7.2.

Syringothyris texta (Hall). Tazawa, 2018a, p. 2, fig. 1.1; Tazawa and Iryu, 2019, p. 105, fig. 7H.

Material.—Three specimens from localities IST1 and KF181, and from the Nashirozawa Valley (exact location unknown) in Shimoarisu: (1) external and internal moulds of a conjoined shell, IGPS112110; (2) internal mould of a conjoined shell, with external mould of the ventral interarea, UHR16925; and (3) internal mould of a ventral valve, IGPS111710.

Remarks.—One of the specimens (UHR16925) was described by Minato (1951, p. 377, pl. 5, fig. 1) as the holotype of *Syringothyris transversa* Minato, 1951. But the Kitakami species is, as discussed by Tazawa (2018a, p. 3), deemed to be a junior synonym of *Syringothyris texta* (Hall, 1857), from the Keokuk Limestone of Missouri and from the Knobstone Formation of Indiana, in the large, transverse shell (length 50 mm, width about 84 mm) and in having a relatively low and slightly concave ventral interarea with a syrinx in the

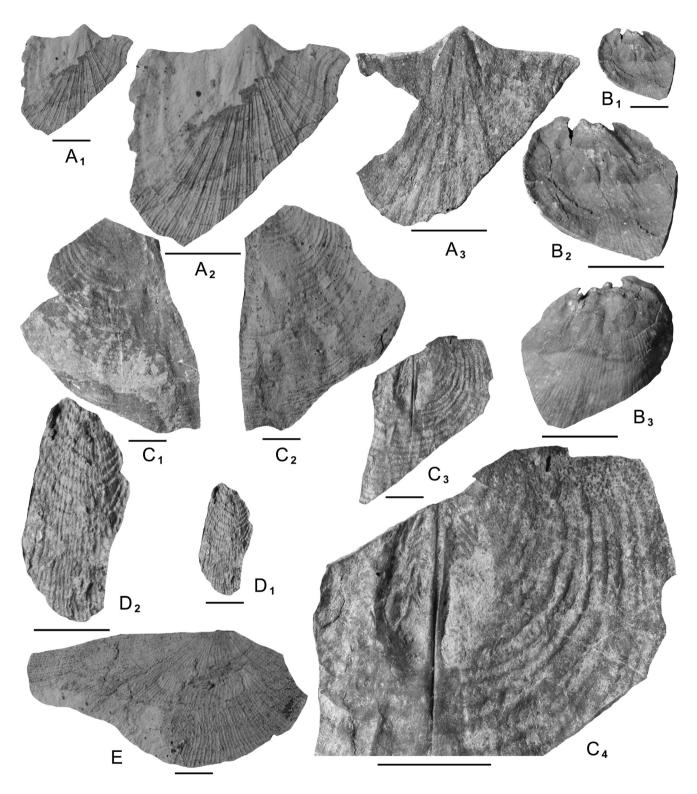


FIGURE 45. Brachiopods of the OD3 assemblage (3). **A,** *Schellwienella radialis* (Phillips), external latex cast (A<sub>1</sub>, A<sub>2</sub>) and internal mould (A<sub>3</sub>) of ventral valve, NU-B2152; **B,** *Rhipidomella michelini* (Léveillé), ventral (B<sub>1</sub>, B<sub>2</sub>) and dorsal (B<sub>3</sub>) views of internal mould of conjoined shell, KCG67; **C,** *Echinaria* sp., external mould (C<sub>1</sub>), external latex cast (C<sub>2</sub>) and internal mould (C<sub>3</sub>, C<sub>4</sub>) of dorsal valve, NU-B2157; **D,** *Fluctuaria undata* (Defrance), external latex cast (D<sub>1</sub>, D<sub>2</sub>) of ventral valve, NU-B2331; **E,** *Orthotetes keokuk* (Hall), external latex cast of ventral valve, KCG69. Scale bars are 1 cm.

delthyrium. *Syringothyris altaica* Tolmatchoff (1924, p. 162, 555, pl. 8, figs. 9–11; pl. 9, fig. 1), from the upper Tournaisian of the Kuznetsk Basin, central Russia, differs from *S. texta* in having blunt cardinal extremities.

Occurrence.—AR2 Unit (Shimoarisu and Yokota).

**Distribution.**—Lower Visean: northeastern Japan (Shimoarisu and Yokota in the South Kitakami Belt) and USA (Indiana and Missouri).

Syringothyris platypleura Weller, 1914 (Fig. 34A, B)

Syringothyris platypleurus Weller, 1914, p. 397, pl. 72, figs. 1–4.

Syringothyris sp. Minato, 1952, p. 165, pl. 5, fig. 2; pl. 9, fig. 1. Syringothyris platypleura Weller. Tazawa and Iryu, 2019, p. 105, fig. 7D, E.

**Material.**—Two specimens from locality IST1, internal moulds of two ventral valves, IGPS111711, 111712.

Remarks.—These specimens were described by Tazawa and Iryu (2019, p. 105, fig. 7D, E) as *Syringothyris platypleura* Weller, 1914. The specimens from Shimoarisu are referred to *S. platypleura* Weller (1914, p. 397, pl. 72, figs. 1–4), from the Burlington Limestone of the Mississippi Valley, in the subpyramidal ventral valve with a very high, flat interarea and nearly flat flanks. *Syringothyris* sp. Minato (1952, p. 165, pl. 5, fig. 2; pl. 9, fig. 1), from the Jumonji Stage (= middle part of the Arisu Formation) of the Yokota area, South Kitakami Belt, is deemed to be a junior synonym of the present species. *Syringothyris kitakamiensis* Minato (1952, p. 165, fig. 5), from the Arisu Formation of the Yokota area, South Kitakami Belt, differs from *S. platypleura* in having a high but slightly concave ventral interarea.

Occurrence.—AR2 Unit (Shimoarisu and Yokota).

**Distribution.**—Upper Tournaisian–lower Visean: northeastern Japan (Shimoarisu and Yokota in the South Kitakami Belt) and USA (Missouri).

Syringothyris sp. (Fig. 42A–C)

**Material.**—Three specimens from locality KF158: (1) external mould of a ventral interarea, NU-B2246; and (2) internal moulds of two ventral valves, NU-B2247, 2248.

**Remarks.**—These specimens are fragmentarily preserved, but can be assigned to the genus *Syringothyris* by the large size, high and flat ventral interarea, and well-developed divergent dental plates in the ventral valve. However, specific identification is difficult for the poorly preserved specimens.

Occurrence.—OD2 Unit (Yokota).

Subfamily PERMASYRINXINAE Waterhouse, 1986 Genus ASYRINXIA Campbell, 1957 **Type species.**—*Spirifera lata* M'Coy, 1847.

Asyrinxia nipponotrigonalis (Minato, 1951) (Figs. 35A, B, 42D)

Fusella nipponotrigonalis Minato, 1951, p. 372, pl. 2, fig. 5; Minato, 1952, p. 160, pl. 5, fig. 1; pl. 6, fig. 6; pl. 11, fig. 3; Minato et al., 1979a, pl. 22, fig. 4.

Fusella nipponotrigonalis var. minor Minato, 1952, p. 160, pl. 6, fig. 3.

Asyrinxia sp. Tazawa, 1981b, p. 74, pl. 5, fig. 14.

Asyrinxia nipponotrigonalis (Minato). Tazawa, 2018a, p. 4, figs. 3.1, 3.2; Tazawa and Ibaraki, 2019, p. 20, fig. 5B.

Material.—Five pecimens from localities IYK3 and KYT3 and from the Otsubosawa Valley (exact location unknown) in Yokota: (1) internal moulds of a conjoined shell, UHR16018 (holotype); (2) external and internal moulds of a dorsal valve, UHR16016; and (3) internal moulds of three dorsal valves, IGPS112130, 112131, NU-B2264.

Remarks.—Most of the specimens were described by Minato (1951, p. 372, pl. 2, fig. 5) as the type specimens of Fusella nipponotrigonalis Minato, 1951. However, as suggested by Campbell (1957, p. 83-84), the Kitakami species is assigned to the genus Asyrinxia, in the large size and in having moderately high, concave ventral interarea, and lacking syrinx. Two syringothyridid species from the Lower Carbniferous of the South Kitakami Belt, Fusella nipponotrigonalis var. minor Minato (1952, p. 160, pl. 6, fig. 3), from the Jumonji and Maide series (= middle and upper parts of the Arisu Formation) of Yokota and Asyrinxia sp. Tazawa (1981b, p. 74, pl. 5, fig. 14), from the Karoyama Formation (= Odaira Formation) of Nisawa, are junior synonyms of the present species. The type species, Asyrinxia lata (M'Coy, 1847), redescribed by Campbell (1957, p. 81, pl. 16, figs. 1–9) from the middle Visean of Babbinboon, New South Wales, eastern Australia, differs from A. nipponotrigonalis by the more transverse outline.

Occurrence.—AR2 Unit (Yokota) and OD2 Unit (Nisawa).

Distribution.—Lower—upper Visean: northeastern Japan (Shimoarisu, Yokota and Nisawa in the South Kitakami Belt).

Asyrinxia sp. (Fig. 42E)

Asyrinxia sp. Tazawa, 1981b, p. 74, pl. 5, fig. 14.

**Material.**—One specimen from locality INS3, internal mould of a ventral valve, IGPS97661.

**Remarks.**—This specimen was described by Tazawa (1981b, p. 74, pl. 5, fig. 14) as *Asyrinxia* sp. The Nisawa specimen somewhat resembles *Asyrinxia lata* (M'Coy, 1847), redescribed by Campbell (1957, p. 81, pl. 16, figs. 1–9) from the middle Visean of New South Wales, eastern Australia, in size, shape and internal structure of the ventral valve. But accurate comparison is difficult for the poorly preserved specimen.

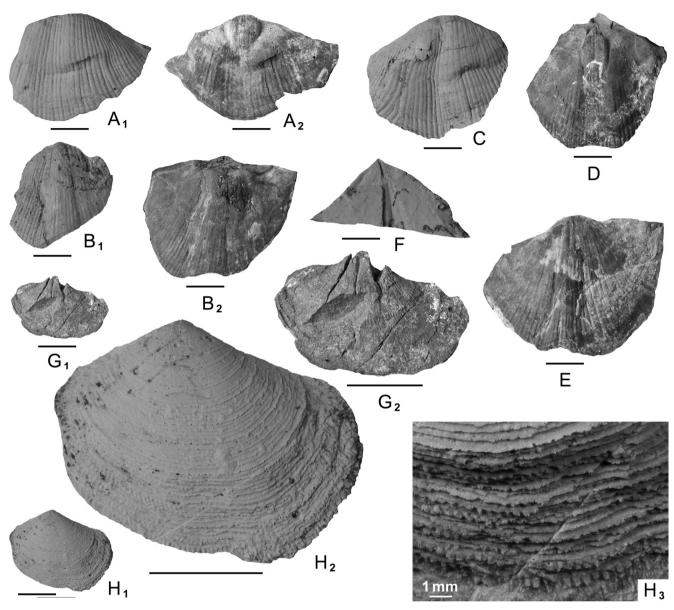


FIGURE 46. Brachiopods of the OD3 assemblage (4). A–E, *Spirifer liangchowensis* Chao; A, external latex cast (A<sub>1</sub>) and internal mould (A<sub>2</sub>) of ventral valve, NU-B2166; B, external latex cast (B<sub>1</sub>) and internal mould (B<sub>2</sub>) of dorsal valve, NU-B2170; C, external latex cast of ventral valve, NU-B2167; D, internal mould of ventral valve, NU-B2168; E, internal mould of dorsal valve, NU-B2171; F, *Pseudosyrinx* sp., external latex cast of ventral interarea, NU-B2163; G, *Kitakamithyris* sp., internal mould (G<sub>1</sub>, G<sub>2</sub>) of ventral valve, NU-B2153; H, *Cleiothyridina fimbriata* (Phillips), external latex cast (H<sub>1</sub>, H<sub>2</sub>) and enlarged microornamentation (H<sub>3</sub>) of dorsal valve, NU-B2164. Scale bars are 1 cm, except for H<sub>3</sub>.

Occurrence.—OD2 Unit (Nisawa).

Genus PSEUDOSYRINX Weller, 1914

**Type species.**—*Pseudosyrinx missouriensis* Weller, 1914.

Pseudosyrinx jumonjiensis (Minato, 1951) (Fig. 35C, D) *Syringothyris jumonjiensis* Minato, 1951, p. 376, pl. 2, fig. 1; Minato et al., 1979a, pl. 21, fig. 12.

*Pseudosyrinx jumonjiensis* (Minato). Tazawa, 2018a, p. 4, fig. 2.1; Tazawa and Iryu, 2019, p. 105, fig. 7F, G.

**Material.**—Four specimens from localities IST1, KF181 and from Shimoarisu (exact location unknown): (1) external mould of a ventral valve, IGPS111713; and (2) external mould of three dorsal valves, IGPS111714, 112090, UHR15995 (holotype).

Remarks.—The holotype (UHR15995) of this species was described by Minato (1951) as *Syringothyris jumonjiensis* Minato, 1951. But the genus of this species, as suggested by Tazawa (2018a, p. 4), should be replaced to *Pseudosylinx*, for the presence of high, flat ventral interarea and lacking syrinx in the delthyrium. The present species most resembles *Pseudosyrinx missouriensis* Weller (1914, p. 406, pl. 65, figs. 5–9; pl. 66, figs. 11–13), from the Burlington Limestone of the Mississippi Valley, in general shape, but the American species is much smaller in size. *Pseudosyrinx sampsoni* (Weller, 1909, p. 311, pl. 14, fig. 4), from the Fern Glen Formation of Missouri, is also a large-sized *Pseudosyrinx* species, but differs from *P. jumonjiensis* in having fewer and stronger costae on the dorsal valve.

Occurrence.—AR2 Unit (Shimoarisu and Yokota).

**Distribution.**—Lower Visean: northeastern Japan (Shimoarisu and Yokota in the South Kitakami Belt).

*Pseudosyrinx* sp. (Fig. 46F)

Pseudosyrinx sp. Tazawa, 2017, p. 340, fig. 8.6.

**Material.**—One specimen from locality KF159, external mould of ventral interarea, NU-B2163.

**Remarks.**—The single specimen from Tairagai was described by Tazawa (2017, p. 340, fig. 8.6) as *Pseudosyrinx* sp. This specimen can be assigned to the genus *Pseudosyrinx* Weller, 1914 in having high interarea with narrowly triangular delthyrium and the absence of syrinx. The Tairagai species somewhat resembles the type species, *Pseudosyrinx missouriensis* Weller (1914, p. 65, figs. 5–9; pl. 66, figs. 11–13), from the Burlington Limestone of the Mississippi Valley, by the high interarea with narrowly triangular delthyrium in the ventral valve. But accurate comparison is difficult in the fragmentarily preserved specimen.

Occurrence.—OD3 Unit (Yokota).

Family DIMEGELASMIDAE Carter in Carter et al., 1994 Genus *DIMEGELASMA* Cooper, 1942

**Type species.**—*Spirifer neglectus* Hall, 1858.

Dimegelasma sp. (Fig. 42F-H)

*Dimegelasma* sp. Tazawa and Katayama, 1979, p. 171, pl. 11, figs. 15, 16; Tazawa, 2018b, p. 74, fig 33A, B.*Tomiopsis* sp. Tazawa, 1984b, p. 308, pl. 61, fig. 10.

**Material.**—Four specimens from locality KF158, internal moulds of three ventral valves, IGPS96135, 96136, NU-B2240, 2241.

Remarks.—Most of the specimens were previously described

by Tazawa and Katayama (1979, p. 171, pl. 11, figs. 15, 16) as Dimegelasma sp. In this paper, two specimens (NU-B2240, 2241) from the same locality (KF158) are added to the material. These specimens can be assigned to the genus Dimegelasma by the medium size (length more than 18 mm, width more than 30 mm in the largest but fragmentarily preserved specimen, IGPS96136), gently convex ventral valve, with rounded cardinal extremities, and by the presence of very long thin dental plates in the ventral valve, *Tomiopsis* sp. Tazawa (1984b, p. 308, pl. 61, fig. 10), from the upper part of the Hikoroichi Formation in the Hikoroichi area, South Kitakami Belt, is conspecific with the present species. The Odaira species superficially resembles Dimegelasma grandicosta (Abramov and Grigorjeva, 1986, p. 162, pl. 29, figs. 4-6; pl. 30, figs. 1, 2, 10), from the middle-upper Visean of the Verkhoyansk Range, northern Russia. Specific identification, however, remains difficult due to the poor preservation of the material.

Occurrence.—OD2 Unit (Yokota).

Suborder SPIRIFERINIDINA Ivanova, 1972 Superfamily PENNOSPIRIFERINOIDEA Dagys, 1972 Family PUNCTOSPIRIFERIDAE Waterhouse, 1975 Genus *PUNCTOSPIRIFER* North, 1920

**Type species.**—*Punctospirifer scabricosta* North, 1920.

Punctospirifer sp. (Fig. 37C)

**Material.**—One specimen from locality KYT1, internal mould of a ventral valve, NU-B2255.

**Remarks.**—The fragmentarily preserved dorsal valve specimen from Yokota is safey assigned to the genus *Punctospirifer* by the small size, transverse outline (length 8 mm, width about 12 mm), smooth, rounded fold and microornament of closey spaced imbricated growth laminae. This specimen resembles shells of *Punctospirifer pauciplicatus* Roberts (1971, p. 265, pl. 58, figs. 17–30), from the Utting Calcarenite of the Bonaparte Gulf Basin, northwestern Australia, in having 3–4 rounded costae on each lateral slope of the dorsal valve. But accurate comparison is difficult for the poorly preserved specimen.

Occurrence.—AR3 Unit (Yokota).

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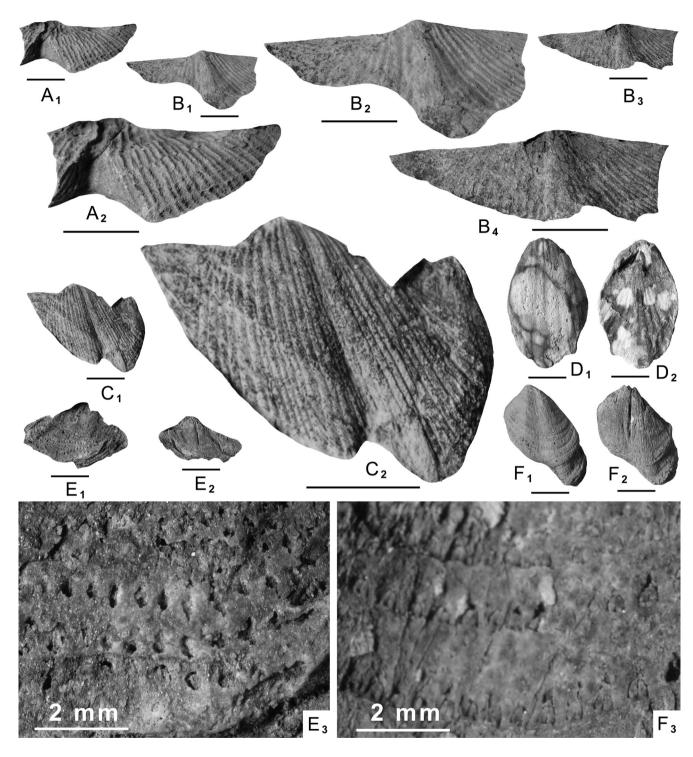


FIGURE 47. Brachiopods of the OD3 assemblage (5). **A, B,** *Imbrexia forbesi* (Norwood and Pratten); A, internal mould (A<sub>1</sub>, A<sub>2</sub>) of ventral valve, KCG80; B, external latex cast (B<sub>1</sub>, B<sub>2</sub>) and internal mould (B<sub>3</sub>, B<sub>4</sub>) of dorsal valve, KCG81; **C,** *Imbrexia incertus* (Hall), external latex cast (C<sub>1</sub>, C<sub>2</sub>) of ventral valve, KCG84; **D,** *Brachythyris chouteauensis* (Weller), ventral (D<sub>1</sub>) and dorsal (D<sub>2</sub>) views of internal mould of conjoined shell, KCG74; **E,** *Kitakamithyris* sp., external mould (E<sub>1</sub>), internal mould (E<sub>2</sub>) and enlarged concentric rows of biramous spine bases (E<sub>3</sub>) of ventral valve, KCG79; **F,** *Torynifer asiatica* Beznossova, external latex cast (F<sub>1</sub>), internal mould (F<sub>2</sub>) and enlarged concentric rows of biramous spine bases (F<sub>3</sub>) of ventral valve, NU-B2332. Scale bars are 1 cm, except for E<sub>3</sub> and F<sub>3</sub>.

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\* : in Japanese \*\* : in Chinese \*\*\* : in Russian

### < 地名・地層名 >

Arisu Formation · · · · · 有住層
Choanji Formation ······ 長安寺層
Dobasawa ····· 堂場沢
"808 m hill" ······ "808 m 高地"
Hikoroichi Formation ······ 日頃市層
Hina ····· 日南
Hinotsuchigawa River ······· 火の土川
Jyumonji ·······················十文字
Kaisenosawa カイセノ沢
Karaumedate Formation · · · · · 唐梅館層
Karosawa Formation ······ 加労沢層
Karoyama Formation 加労山層
Kesengawa River ····· 気仙川
Kesen-gun ····· 気仙郡
Komatagawa River ······ 小股川
Kominekurasawa ······ 小峰倉沢
Konikurazawa ······ 小仁倉沢
Maide ····· 舞出
Mt. Karoyama ······ 加労山

Mt. Odairayama ····· 大平山
Myojinsawa ······ 明神沢
Nagaiwa Formation · · · · 長岩層
Nagasaka ····· 長坂
Nashirozawa ナシロ沢
Nekonosawa 猫ノ沢
Nisawa ····· 荷沢
Nisawa Pass ····· 荷沢峠
North China Province · · · · · 北中国区
Odaira Formation · · · · 大平層
Okuhinotsuchi 奥火の土
Omatagawa River ····· 大股川
Onimaru Formation ······ 鬼丸層
Otomo-cho ······· 小友町
Otsubosawa ······ 小坪沢
Rikuzentakata City ······· 陸前高田市
Sasanohora Formation · · · · · 笹ノ洞層
Senbakaya Formation · · · · · · · 仙婆嚴層
Shiba Formation ······· 芝層
>

Shimoarisu ······ 下有	住
Shittakazawa Formation	
Shizu ····· 清	水
Shokarosawa 小加労	沢
Soma ····· 柞	馬
Suesawa ····· 末	沢
Suisawa スイ	沢
Sumita-cho ······ 住田	
Tairagai ······ 🏋	
Takase ·····	瀬
Tono City ······ 遠野	
Yahagi 矢	作
Yahagigawa River ····· 矢作	:][[
Yasumotozawa ヤスモト	
Yokokawa River ····· 横	
Yokota ····· 横	田
Yonesato Formation ····· 米里	
Yukisawa ····· f	沢

#### APPENDIX

- AOD1: Yokota area (39°05′17″ N, 141°34′20″ E), south-facing slope, 400 m N of junction of the Otsubosawa and Kaisenosawa valleys, light greenish grey coarse-grained tuffaceous sandstone, lower OD2 Unit of the Odaira Formation, with *Absenticosta uldzejtuensis*.
- INS1: Nisawa area (39°13′28″ N, 141°28′06″ E), middle Dobasawa Valley; dark grey shale, upper OD2 Unit of the Odaira Formation, with *Martinia georgei*.
- INS2: Nisawa area (39° 13′24″ N, 141° 28′15″ E), middle Dobasawa Valley, dark grey shale, upper OD2 Unit of the Odaira Formation, with *Fluctuaria undata*, *Schizophoria resupinata* and *Martinia georgei*.
- INS3: Nisawa area (39° 13′24″ N, 141° 28′19″ E), middle Dobasawa Valley; greenish grey tuff, middle OD2 Unit of the Odaira Formation, with *Marginicinctus marginicinctus*, *Martinia georgei* and *Asyrinxia* sp.
- INS4: Nisawa area (39°12′22″ N, 141°28′02″ E), western slope of "808 m hill", 750 m NE of Nisawa Pass, greenish grey tuff, middle OD2 Unit of the Odaira Formation, with *Martinia georgei*.
- INS5: Nisawa area (39°12′18″ N, 141°28′24″ E), upper Karosawa Valley, greenish grey tuff, middle OD2 Unit of the Odaira Formation, with *Martinia georgei*.
- INS6: Nisawa area (39°11′54″ N, 141°28′15″ E), ridge between the Karosawa Valley and the Komatagawa River, grey fine-grained calcareous sandstone, OD3 Unit of the Odaira Formation, with *Martinia georgei*.
- INS7: Nisawa area (39° 11′39″ N, 141° 28′23″ E), middle Karosawa Valley, grey limestone, middle OD2 Unit of the Odaira Formation, with *Levitusia elongata* sp. nov., *Orthotetes keokuk*, *Schizophoria resupinata* and *Martinia georgei*.
- INS8: Nisawa area (39°11′27″ N, 141°28′30″ E), middle Shokarosawa Valley, greenish grey tuff, middle OD2 Unit of the Odaira Formation, with *Martinia georgei*.
- INS9: Nisawa area (39°11′35″ N, 141°28′53″ E), upper Shokarosawa Valley, black shale, lower OD2 Unit of the Odaira Formation, with *Schizophoria resupinata*.
- INS10: Nisawa area (39°11'37" N, 141°28'59" E), upper Shokarosawa Valley, greenish grey tuff, lower OD2 Unit of the Odaira Formation, with *Schizophoria resupinata* and *Martinia georgei*.
- INS11: Nisawa area (39°11'22" N, 141°29'04" E), upper Nekonosawa Valley, greenish grey tuff, lower OD2 Unit of the Odaira Formation, with *Levitusia elongata* sp. nov. and *Schizophoria resupinata*.
- INS12: Nisawa area (39° 11′01″ N, 141° 28′42″ E), middle Nekonosawa Valley, grey medium-grained sandstone, upper OD2 Unit of the Odaira Formation, with *Striatifera angusta*.
- INS13: Nisawa area (39° 10′52″ N, 141° 28′42″ E), middle Nekonosawa Valley, grey medium-grained sandstone, upper OD2 Unit of the Odaira Formation, with *Marginicinctus marginicinctus*, *Schizophoria resupinata* and *Martinia georgei*.

- IST1: Shimoarisu area (39° 11′06″ N, 141° 32′06″ E), road cutting beside the lower Hinotsuchigawa River, 125 m SE of junction of the Hinotsuchigawa River and Shittakazawa Valley, dark grey calcareous shale, lower AR2 Unit of the Arisu Formation, with Ovatia elongata, Rhipidomella michelini, Schizophoria resupinata, S. pinguis, S. woodi, Unispirifer striatoconvolutus, Unispirifer sp., Kitakamithyris hikoroitiensis, Syringothyris texta, S. platypleura and Pseudosyrinx jumonjiensis.
- IYK1: Yokota area (39° 06′41″ N, 141° 33′53″ E), northeastern slope of Mt. Odairayama, dark grey calcareous sandstone, upper AR2 Unit of the Arisu Formation, with *Tomiproductus elegantulus*, *Rhipidomella michelini* and *Kitakamithyris hikoroitiensis*.
- IYK2: Yokota area (39° 06′41″ N, 141° 33′47″ E), northeastern slope of Mt. Odairayama, dark grey calcareous sandstone, upper AR2 Unit of the Arisu Formation, with *Tomiproductus elegantulus*, *Marginatia burlingtonensis* and *Cleiothyridina harkeri*.
- IYK3: Yokota area (39°06'42" N, 141°33'42" E), northeastern slope of Mt. Odairayama, dark grey calcareous sandstone, upper AR2 Unit of the Arisu Formation, with Marginatia burlingtonensis and Asyrinxia nipponotrigonalis.
- KAR1: Okuhinotsuchi area (39° 11′36″ N, 141° 30′47″ E), small tributary on the northern bank of the Hinotsuchigawa River, 1.4 km NW of junction of the Hinotsuchigawa and Yokokawa rivers, light grey tuffaceous shale, lower ST3 Unit of the Shittsakazawa Formation, with Rhipidomella kusbassica, Schizophoria pinguis, S. mayesensis and Unispirifer kozuboensis.
- KAR4: Shizu area (39°09′54″ N,141°31′18″ E), middle Yasumotozawa Valley, greenish-grey medium-grained tuffaceous sandstone, middle AR2 Unit of the Arisu Formation, with *Grandispirifer mylkensis*.
- KAR6: Okuhinotsuchi area (39° 10′26″ N, 141° 31′05″ E), upper Yasumotozawa Valley, greenish grey coarse-grained tuffaceous sandstone, lower AR2 Unit of the Arisu Formation, with *Grandispirifer mylkensis*.
- KAR11: Okuhinotsuchi area (39°11′52″ N, 141°30′53″ E), ridge between the Yokokawa and Hinotsuchigawa rivers, 0.8 km N of Okuhinotsuchi, greenish grey coarse-grained tuffaceous sandstone, middle AR2 Unit of the Arisu Formation, with *Levitusia humerosa*.
- KF158: Yokota area (39° 05′ 05″ N, 141° 34′ 09″ E), road cutting at 30 m W of junction of the Otsubosawa and Kaisenosawa valleys, light greenish grey coarse-grained tuffaceous sandstone, lower OD2 Unit of the Odaira Formation, with *Rhipidomella michelini*, *Schizophoria resupinata*, *Spirifer liangchowensis*, *Syringothyris* sp. and *Dimegelasma* sp.
- KF159: Yokota area (39°04'38" ON, 141°34'30" E), road cutting along the lower Tairagaisawa Valley; dark grey calcareous shale, OD3 Unit of the Odaira Formation, with Leptagonia analoga, Rugosochonetes extensus,

Marginatia burlingtonensis, Echinoconchus punctatus, Echinaria sp., Pustula pustulosa, Schellwienella radialis, Cleiothyridina fimbriata, Spirifer liangchowensis, Kitakamithyris sp. and Pseudosyrinx sp.

- KF175: Yokota area (39°05′07″ N, 141°33′15″ E), south-facing slope 350 m W of junction of the Otsubosawa and Myojinsawa valleys, light greenish-grey coarse-grained tuffaceous sandstone, lower OD2 Unit of the Odaira Formation, with *Rhipidomella michelini*.
- KF177: Yokota area (39°05'05" N, 141°33'16" E), middle Otsubosawa Valley, 350 m W of junction of the Otsubosawa and Myojinsawa valleys, light greenish grey coarse-grained tuffaceous sandstone, lower OD2 Unit of the Odaira Formation, with *Schizophoria resupinata*.
- KF179: Yokota area (39° 05′21″ N, 141° 33′23″ E), middle Myojinsawa Valley, light greenish grey coarse-grained tuffaceous sandstone, lower AR2 Unit of the Arisu Formation, with Tolmatchoffia robusta, Tomiproductus elegantulus, Orthotetes keokuk, Rhipidomella michelini, Schizophoria pinguis, Unispirifer striatoconvolutus, U. kozuboensis and Kitakamithyris hikoroitiensis.
- KF180: Yokota area (39° 05′ 23″ N, 141° 33′ 22″ E), middle Myojinsawa Valley, light greenish grey coarse-grained tuffaceous sandstone, lower AR2 Unit of the Arisu Formation, with *Tomiproductus elegantulus*, *Rhipidomella michelini*, *Schizophoria pinguis* and *Acuminothyris triangularis*.
- KF181: Yokota area (39° 05′25″ N, 141° 33′20″ E), middle Myojinsawa Valley, light greenish grey coarse-grained tuffaceous sandstone, lower AR2 Unit of the Arisu Formation, with Tolmatchoffia robusta, Tomiproductus elegantulus, Orthotetes keokuk, Rhipidomella michelini, Schizophoria pinguis, Grandispirifer mylkensis, Unispirifer kozuboensis, Syringothyris texta and Pseudosyrinx jumonjiensis.
- KF207: Yokota area (39° 05′ 04″ N, 141° 33′ 56″ E), road cutting along the middle Otsubosawa Valley, 50 m W of junction of Otsubosawa and Suesawa valleys, black shale, upper AR3 Unit of the Arisu Formation, with *Orbiculoidea* sp., *Marginatia burlingtonensis* and *Brachythyrina* sp.
- KF208: Yokota area (39° 05′ 06″ N, 141° 34′ 02″ E), road cutting along middle Otsubosawa Valley, 75 m E of junction of Otsubosawa and Suesawa valleys, black shale, lower AR3 Unit of the Arisu Formation, with *Marginatia burlingtonensis*.
- KF210: Yahagi area (39° 02′31″ N, 141° 35′08″ E), road cutting along the lower YukisawaValley, at 1 km W of junction of the Yukisawa Valley and the Kesengawa River, grey calcareous shale, upper OD3 Unit of the Odaira Formation, with *Marginicinctus marginicinctus*,

- Fluctuaria undata and Torynifer asiatica.
- KYT1: Yokota area (39°05′20″ N, 141°33′57″ E), middle Suesawa Valley, black shale, lower AR3 Unit of the Arisu Formation, with *Unispirifer minnewankensis* and *Punctospirifer* sp.
- KYT2: Yokota area (39° 05′ 48″ N, 141° 33′ 39″ E), upper Suesawa Valley, greenish grey fine-grained tuffaceous sandstone, lower AR2 Unit of the Arisu Formation, with *Martinia georgei* and *Unispirifer kozuboensis*.
- KYT3: Yokota area (39° 05′ 41″ N, 141° 33′ 45″ E), upper Suesawa Valley, light greenish grey coarse-grained tuffaceous sandstone, lower AR2 Unit of the Arisu Formation, with *Marginatia burlingtonensis*, *Acuminothyris triangularis* and *Asyrinxia nipponotrigonalis*.
- KYT4: Yokota area (39° 05′ 41″ N, 141° 33′ 39″ E), upper Suesawa Valley, light greenish grey coarse-grained tuffaceous sandstone, lower AR2 Unit of the Arisu Formation, with *Acuminothyris triangularis*.
- YKA12:Shizu area (39°09'44" N, 141°29'13" E), near the mouth of the Konikurazawa Valley, greenish grey fine-grained tuffaceous sandstone, upper OD2 Unit of the Odaira Formation, with *Levitusia elongata* sp. nov.
- YKA16:Shizu area (39° 09′ 00″ N, 141° 29′ 41″ E), road cutting along the Omatagawa River, at 1.3 km SW of junction of the Omatagawa and Komatagawa rivers, greenish grey fine-grained tuffaceous sandstone, middle OD2 Unit of the Odaira Formation, with *Rhipidomella michelini* and *Schizophoria resupinata*.
- YKA18: Shizu area (39°08′42″ N, 141°29′53″ E), lower Suisawa Valley, greenish grey fine-grained tuffaceous sandstone, lower OD2 Unit of the Odaira Formation, with *Schizophoria resupinata*.
- YKA20: Shizu area (39°08'41" N, 141°29'55" E), lower Suisawa Valley, greenish grey fine-grained tuffaceous sandstone, lower OD2 Unit of the Odaira Formation, with Absenticosta uldzejtuensis, Orthotetes keokuk, Schizophoria resupinata and Rotaia hikoroichiensis.
- YKA21: Shizu area (39°08'30" N, 141°29'43" E), middle Kominekurasawa Valley, greenish grey fine-grained tuffaceous sandstone, lower OD2 Unit of the Odaira Formation, with *Levitusia elongata* sp. nov., *Schizophoria resupinata* and *Spirifer liangchowensis*.
- YUK1: Yahagi area (39°02'26" N, 141°34'40" E), southern slope facing the middle Yukisawa Valley, grey calcareous shale, upper OD3 Unit of the Odaira Formation, with Rugosochonetes extensus, Rugosochonetes sp., Plicatifera plicatilis, P. pseudoplicatilis, Argentiproductus sp., Alitaria konincki, Orthotetes keokuk, Rhipidomella michelini, Imbrexia forbesi, Brachythyris chouteauensis and Kitakamithyris sp.