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# EARLY CARBONIFEROUS (MISSISSIPPIAN) BRACHIOPODS FROM THE HIKOROICHI FORMATION, SOUTH KITAKAMI BELT, JAPAN

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## ABSTRACT

This study describes an early Carboniferous brachiopod fauna (the Hikoroichi fauna), consisting of 51 species in 36 genera, including two new species (*Leiochonetes onimarensis* sp. nov. and *Punctospirifer iwatensis* sp. nov.), from the lower part (HK1 Unit), the middle part (HK2 Unit) and the upper part (HK4 Unit) of the Hikoroichi Formation in the Hikoroichi area, South Kitakami Belt, northeastern Japan. The HK1 assemblage (18 species in 16 genera) indicates a late Tournaisian age, the HK2 assemblage (28 species in 23 genera) indicates an early Visean age, and the HK4 assemblage (15 species in 15 genera) indicates a late Visean age. Thus, the Hikoroichi Formation is correlated with the upper Tournaisian–upper Visean. In terms of palaeobiogeography, the three assemblages have close affinities with the early Carboniferous brachiopod faunas of North America (Missouri and Iowa), western Europe (England), northern Russia (Verkhoyansk Range), central Russia (southern Urals and Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang). In other words, the Hikoroichi fauna is allied with those of the North China Province in northwestern–northeastern China. Thus, the South Kitakami region was probably located at the eastern extension of the province, namely east to the North China (Sino-Korea) block in the early Carboniferous.

Key words : Brachiopoda, early Carboniferous, Hikoroichi fauna, Japan, South Kitakami Belt

**田沢純一（2018）南部北上帯の日頃市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 17: 27–87.**

南部北上帯日頃市地域に分布する日頃市層の下部（HK1 ユニット），中部（HK2 ユニット），上部（HK4 ユニット）から産出する 36 属 51 種の前期石炭紀腕足類（日頃市フォーナ）を記載した．これらのなかには 2 種の新種（*Leiochonetes onimarensis* sp. nov., *Punctospirifer iwatensis* sp. nov.）が含まれる．HK1 群集（16 属 18 種）は後期Tournaisian，HK2 群集（23 属 28 種）は前期Visean，HK4 群集（15 属 15 種）は後期Viseanを示す．したがって，日頃市層は上部Tournaisian～上部Viseanに対比される．古生物地理学的に，HK1，HK2，HK4 群集はいずれも北アメリカ（ミズーリ州，アイオワ州），西ヨーロッパ（イングランド），ロシア北部（ベルホヤンスク山脈），ロシア中央部（ウラル山脈南部，クズネツク盆地），カザフスタン，中国西北部（新疆）などの前期石炭紀腕足類フォーナに近縁である．すなわち日頃市フォーナは中国西北部～東北部に分布する中国北方区の前期石炭紀腕足類フォーナに種属構成が類似する．このことから，前期石炭紀に南部北上帯は中国北方区の東方延長部に位置し，北中国（中朝地塊）の東方に存在したと推定される．

## INTRODUCTION

The South Kitakami Belt of northeastern Japan contains excellent sections of lower Carboniferous (Mississippian) rocks. The Hikoroichi area in the eastern part of the South Kitakami Belt (i.e., Hikoroichi-cho, Ofunato City, Iwate Prefecture; Figs. 1 and 2) is a classical and important area for the lower Carboniferous stratigraphy of Japan as well as the South Kitakami Belt. Since the work of Onuki (1937) and Yabe and Sugiyama (1937), many studies have investigated the stratigraphy of the lower Carboniferous rocks in the Hikoroichi area (e.g., Minato, 1950b; Okubo, 1951; Minato et al., 1953, 1979b, 1979c; Onuki, 1969; Mori and Tazawa, 1980; Tazawa, 1981a, 1984b; Kawamura, 1983).

The lower Carboniferous rocks of the Hikoroichi area are

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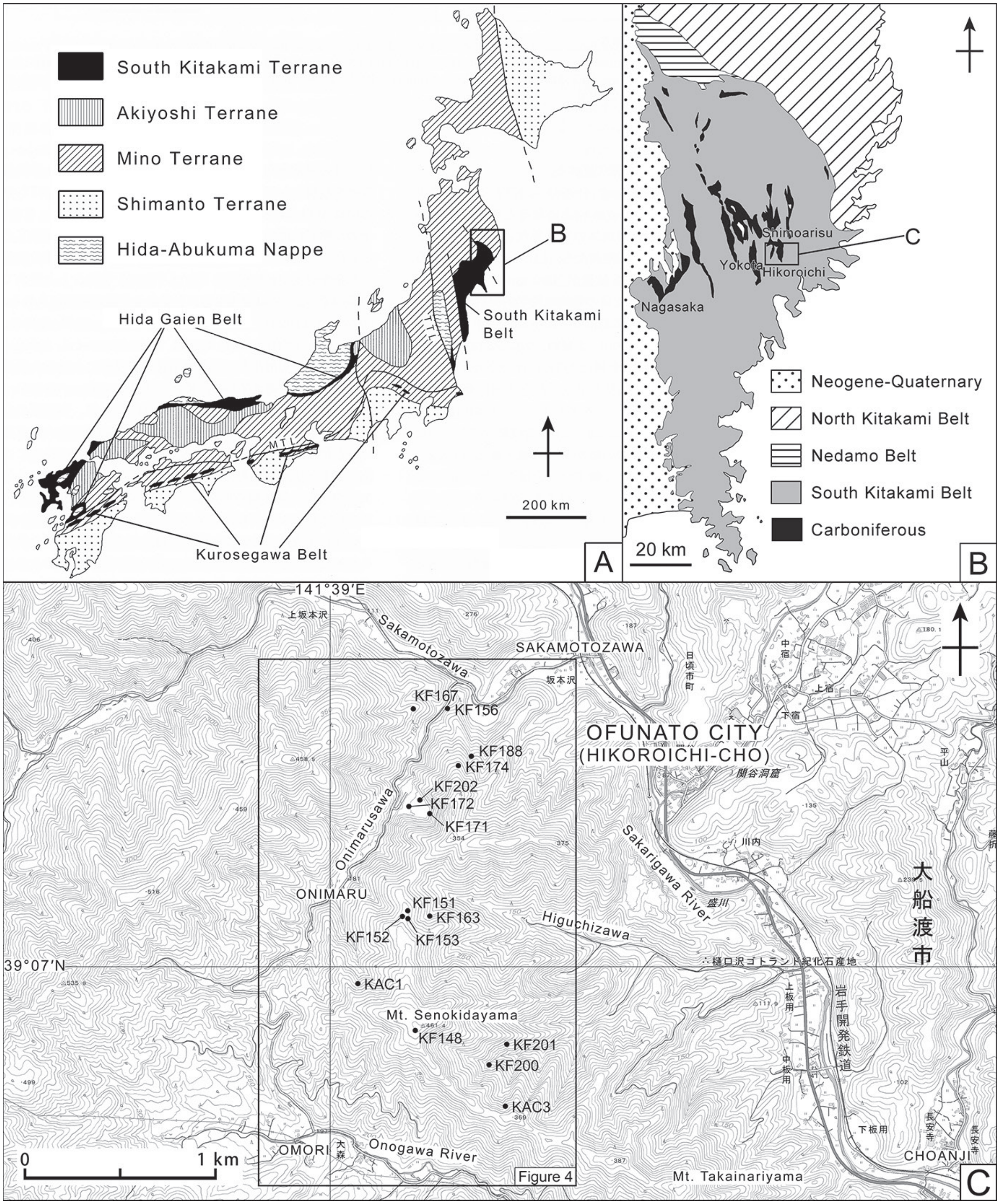


FIGURE 1. Maps showing the location and geology of the Hikoroichi area, South Kitakami Belt. (**A**) Geotectonic map of the Japanese Islands, showing the distribution of the South Kitakami Belt (based on Tazawa, 2004); (**B**) geotectonic map of the northeastern part of Honshu, Japan, showing the distribution of the Carboniferous rocks in the South Kitakami Belt (based on Kawamura et al., 2013); and (**C**) topographical map showing the mapped area and fossil localities in the Hikoroichi area, South Kitakami Belt (using the electronic topographical map of GSI).

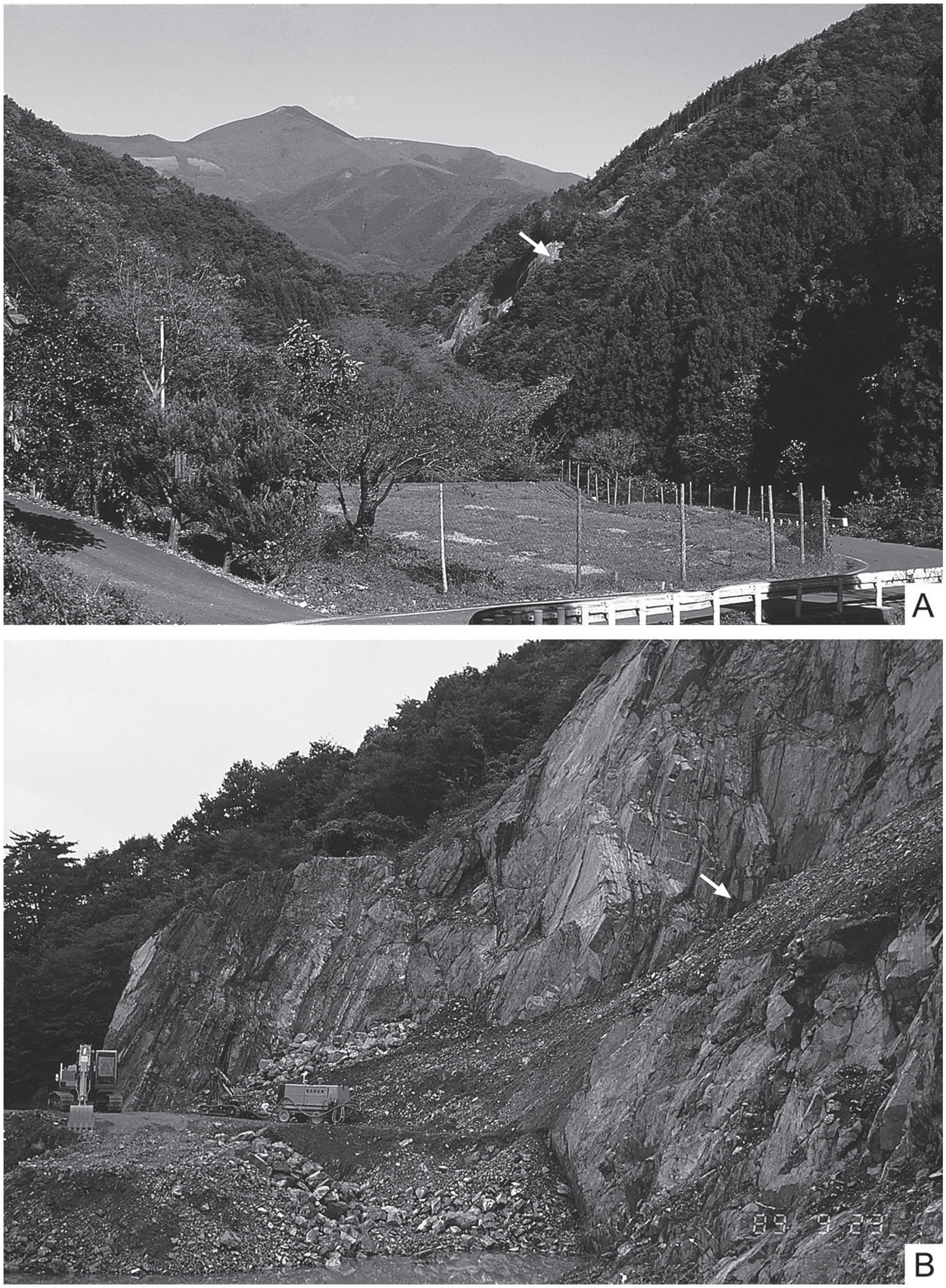

FIGURE 2. A distant view (**A**) and a close view (**B**) of the outcrop of sandstone and shale of the HK2 Unit of the Hikoroichi Formation in the Onimaru quarry, Hikoroichi-cho, Ofunato City, Iwate Prefecture. Arrows show the fossil locality KF202. Mt. Goyosan in the background is composed of Cretaceous granitic rocks.

divided into two formations: the Tournaisian–upper Visean, volcaniclastic-dominated Hikoroichi Formation and the upper Visean, limestone-dominated Onimaru Formation (Minato, 1950b; Kawamura, 1983; Tazawa, 1984b, 1985). However, the age of the lower part of the Hikoroichi Formation is poorly constrained because of a lack of palaeontological data. Brachiopods are the most common megafossils in the Hikoroichi Formation of the Hikoroichi area, and 23 species in 20 genera have been described

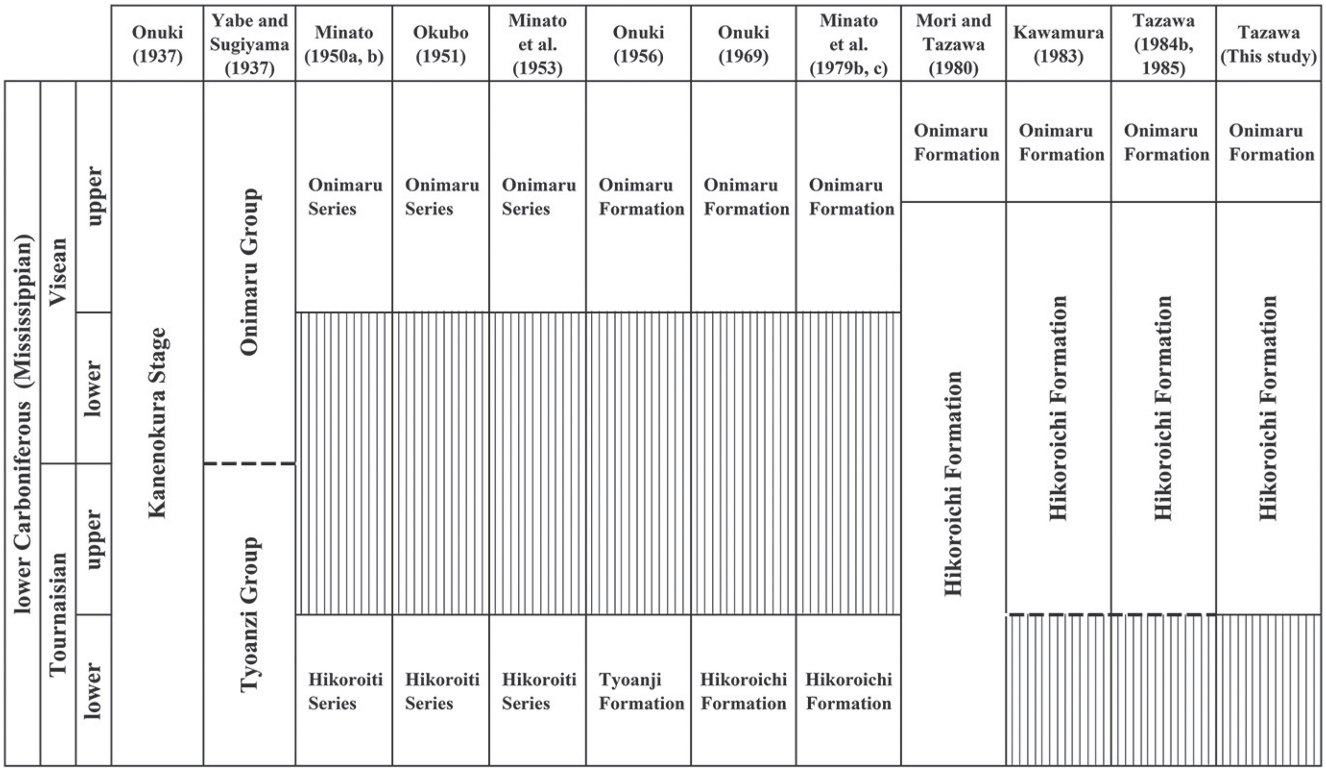


FIGURE 3. Comparison of stratigraphic schemes proposed for the lower Carboniferous formations in the Hikoroichi area, South Kitakami Belt.

by Minato (1951, 1952, 1953), Minato and Kato (1977), Tazawa (1984a, 1984b, 1985, 1989, 1996, 2006) and Tazawa and Ibaraki (2009). However, these brachiopods were obtained and described mostly from the middle and upper parts of the Hikoroichi Formation. Thus, the brachiopod species from the lower part of the Hikoroichi Formation are poorly known.

In this study, I describe brachiopods from the lower part (HK1 Unit), the middle part (HK2 Unit) and the upper part (HK4 Unit) of the Hikoroichi Formation in the Hikoroichi area, and discuss the age and palaeobiogeography of the Hikoroichi fauna (HK1, HK2 and HK4 assemblages). Most of the materials were collected by the present author; the rest were provided by M. Harashinai, T. Kawamura and A. Kaneko. The specimens described herein are registered and stored in the Department of Geology, Niigata University, Niigata (NU-B prefix) and the Tohoku University Museum, Sendai (IGPS prefix).

## PREVIOUS WORK

### Stratigraphy

Previous studies on the stratigraphy of the lower Carboniferous rocks in the Hikoroichi area are summarized in Fig. 3. In the early studies of the area, Onuki (1937) and Yabe and Sugiyama (1937) named the lower Carboniferous rocks the Kanenokura Stage and the Tyoanzi (Choanji) and Onimaru Groups, respectively. Minato (1950b) established the Hikoroiti (Hikoroichi) Series (Etroeungtian–lower Tournaisian) for the lower strata and the Onimaru Series (upper Visean) for the upper strata. Furthermore, Minato (1950a) emphasized the pre-Onimaru hiatus as evidence of the "Shizu Folding", one of the Palaeozoic orogenic events recorded in the South Kitakami region. This proposal was accepted by many workers (e.g., Okubo, 1951; Minato et al., 1953, 1979b, 1979c; Minato, 1955, 1966; Onuki, 1956, 1969). Subsequently, Mori and Tazawa (1980) revealed that the Onimaru Formation conformably overlies the Hikoroichi Formation in the Hikoroichi area. This new finding was supported and strengthened by stratigraphical studies (Tazawa, 1981a, 1984b: Kawamura, 1983) and palaeontological studies (Kawamura, 1983; Tazawa, 1984a, b, 1985, 2006).

Recently, Tazawa (2017a) and Tazawa and Niikawa (2018) described the Late Devonian brachiopods, *Cyrtospirifer choanjiensis*, *Cyrtospirifer* sp. 1, *Cyrtospirifer* sp. 2 and *Desquamatia* (*Seratrypa*) sp., from sandstone and shale that had been previously assigned to the Hikoroichi Formation at Choanji, just east to the Hikoroichi area (Fig. 1C). Tazawa and Niikawa (2018) redefined the fossil-bearing sandstone and shale of Choanji as the Upper Devonian (Frasnian–Famennian) Choanji Formation. Thus, the Hikoroichi Formation is now restricted to the Hikoroichi area and does not occur in the Choanji area.

### Palaeontology

Many studies have examined on the fossils of the Hikoroichi

Formation, including rugose corals (Kawamura, 1983; Kato et al., 1989), tabulate corals (Kawamura, 1983; Kato et al., 1989), bryozoans (Sakagami, 1962, 1989), brachiopods (Minato, 1951, 1952, 1953; Minato and Kato, 1977; Tazawa, 1984a, b, 1985, 1989, 1996, 2006; Tazawa and Ibaraki, 2009), gastropods (Kase, 1988, 1989), cephalopods (Niko, 1989), trilobites (Kobayashi and Hamada, 1980; Kaneko, 1983, 1986, 1989), crinoids (Minato, 1951) and land plants (Asama et al., 1985, 1989). However, most of these studies focussed on materials from the middle and upper parts of the Hikoroichi Formation.

In terms of biostratigraphy, the upper part of the Hikoroichi Formation is correlated with the upper Visean on the basis of rugose corals such as *Amygdalophyllum etheridgei*, *Dibunophyllum* sp., *Koninckophyllum* sp. and *Siphonodendron* sp. (Mori and Tazawa, 1980; Kawamura, 1983) and brachiopods such as *Schizophoria resupinata*, *Orthotetes* sp., *Pustula* cf. *pustulosa*, *Karavankina* sp. and *Choristites bisulcatus* (Mori and Tazawa, 1980; Tazawa, 1984b). The middle part of the formation is correlated with the lower Visean on the basis of rugose corals such as *Amygdalophyllum etheridgei*, "*Lophophyllidium*" sp. and *Multithecopora* sp. (Kawamura, 1983) and brachiopods such as *Marginatia burlingtonensis*, *Syringothyris transversa*, *Rotaia hikoroichiensis*, *Linoprotonia ashfellensis* and *Gigantoproductus* cf. *crassiventer* (Tazawa, 1985, 2006; Tazawa and Ibaraki, 2009). However, the age of the lower part of the Hikoroichi Formation is unclear. Kawamura (1983) suggested a late Tournaisian age based on rugose corals, *Caninia cornucopiae*, *Palaeosmilia* sp., *Amygdalophyllum* sp. and *Cyathaxonia* sp., although the corals remain undescribed. Minato (1950b) considered that the Hikoroichi Series is correlated with the Etroeungtian–lower Tournaisian based on brachiopods, mostly from Choanji. However, as mentioned above, the fossil-bearing beds of Choanji are assigned to the Upper Devonian Choanji Formation, not to the Hikoroichi Formation.

In terms of palaeobiogeography, Tazawa (2002, 2006) concluded that the South Kitakami region was the eastern extension of the Tianshan–Jilin Province of Yang (1994), and was located on the continental shelf bordering the eastern margin of North China (Sino-Korea) in the early Visean, as inferred from the *Marginatia*–*Syringothyris*–*Rotaia* brachiopod assemblage from the middle part of the Hikoroichi Formation and equivalent faunas in the Shimoarisu and Yokota areas in the South Kitakami Belt.

## STRATIGRAPHY AND MATERIALS

Carboniferous rocks crop out in the Hikoroichi area, forming a syncline that plunges gently to the north (Fig. 4). The strata are subdivided lithologically into three formations: the Hikoroichi Formation (upper Tournaisian–upper Visean; this study), the Onimaru Formation (upper Visean; Minato and Kato, 1979) and the Nagaiwa Formation (Serpukhovian–Moscovian; Kato and Nakamura, 1979), in ascending order (Fig. 5). According to Tazawa (1984b), the Hikoroichi Formation consists mostly of sandstone, with subordinate shale, conglomerate, tuff and arenaceous limestone, and has a total thickness of 440–560 m. The formation overlies the Middle Devonian Nakazato Formation across an angular unconformity, and is in turn conformably overlain by the Onimaru Formation.

In this paper, I propose three parts (the lower, middle and upper parts) and four lithostratigraphic units (the HK1, HK2, HK3 and HK4 units) in the Hikoroichi Formation. The lower part consists of the HK1 Unit (mainly sandstone with subordinate shale, felsic tuff and arenaceous limestone, 133–207 m in total thickness); the middle part consists of both the HK2 Unit (mainly shale, with subordinate sandstone and arenaceous limestone, 67–100 m in total thickness) and the HK3 Unit (mainly andesitic to basaltic tuff, with subordinate sandstone, shale and arenaceous limestone, 40–87 m in total thickness); and the upper part consists of the HK4 Unit (mainly sandstone, with subordinate shale and arenaceous limestone, 147–240 m in total thickness). Brachiopods described herein were collected from 16 localities (stations): three localities (KAC3, KF200 and KF201) in the HK1 Unit, five localities (KF171, KF172, KF174, KF188 and KF202) in the HK2 Unit, and eight localities (KF156, KF167, KAC1, KF148, KF163, KF152, KF151 and KF153) in the HK4 Unit. The topographic and stratigraphic locations, lithologies and brachiopod species of the 16 fossil localities are indicated in Figs. 1, 5, 6 and summarized in Appendix.

## HIKOROICHI FAUNA

The brachiopods described herein are the following 51 species in 36 genera, including two new species (*Leiochonetes onimarensis* sp. nov. and *Punctospirifer iwatensis* sp. nov.): *Leptagonia analoga* (Phillips, 1836), *Rugosochonetes* cf. *hardrensis* (Phillips, 1841), *Plicochonetes* sp., *Leiochonetes onimarensis* sp. nov., *Argentiproductus margaritaceus* (Phillips, 1836), *Tolmatchoffia robusta* (Tolmatchoff, 1924), *Marginatia burlingtonensis* (Hall, 1858), *M. magna* Carter, 1968, *Echinoconchus punctatus* (Sowerby, 1822), *Karavankina jizodoensis* Tazawa, 1980, *Pustula pustulosa* (Phillips, 1836), *Ovatia laevicosta* (White, 1860), *O.* cf. *prolata* Carter, 1987, *Ovatia* sp., *Linoprotonia ashfellensis* Ferguson, 1971, *L. hikoroichiensis* Tazawa and Ibaraki, 2009, *Gigantoproductus crassiventer* (Prentice, 1949), *G. latiexpansus* Sarytcheva in Sarytcheva and Sokolskaya, 1952, *Orthotetes keokuk* (Hall, 1858), *Rhipidomella michelini* (Léveillé, 1835), *Schizophoria resupinata* (Martin, 1809), *Rhynchopora* sp., *Rotaia hikoroichiensis* Tazawa, 2006, *Actinoconchus expansus* (Phillips, 1836), *A. paradoxus* M'Coy, 1844, *Lamellosathyris qaidamensis* Chen, Shi and Zhan, 2003, *Cleiothyridina harkeri* Carter, 1987, *Cleiothyridina* sp., *Hustedia* sp., *Spirifer liangchowensis* Chao, 1929, *S. karagai* (Litvinovich, 1962), *Unispirifer striatoconvolutus* (Dun and Benson, 1920), *U. mediocris* (Tolmatchoff, 1924), *U. kozuboensis* (Minato, 1952), *Angiospirifer bisulcatus* (Sowerby, 1825), *Tegulocrea incerta* (Hall, 1858), *Acuminothyris triangularis* Roberts, 1963, *A. keokuk* Carter, 1990, *Brachythyris suborbicularis* (Hall, 1858), *Tylothyris laminosa* (M'Coy, 1844), *Kitakamithyris tyoanjiensis* Minato, 1951, *K. hikoroitiensis*

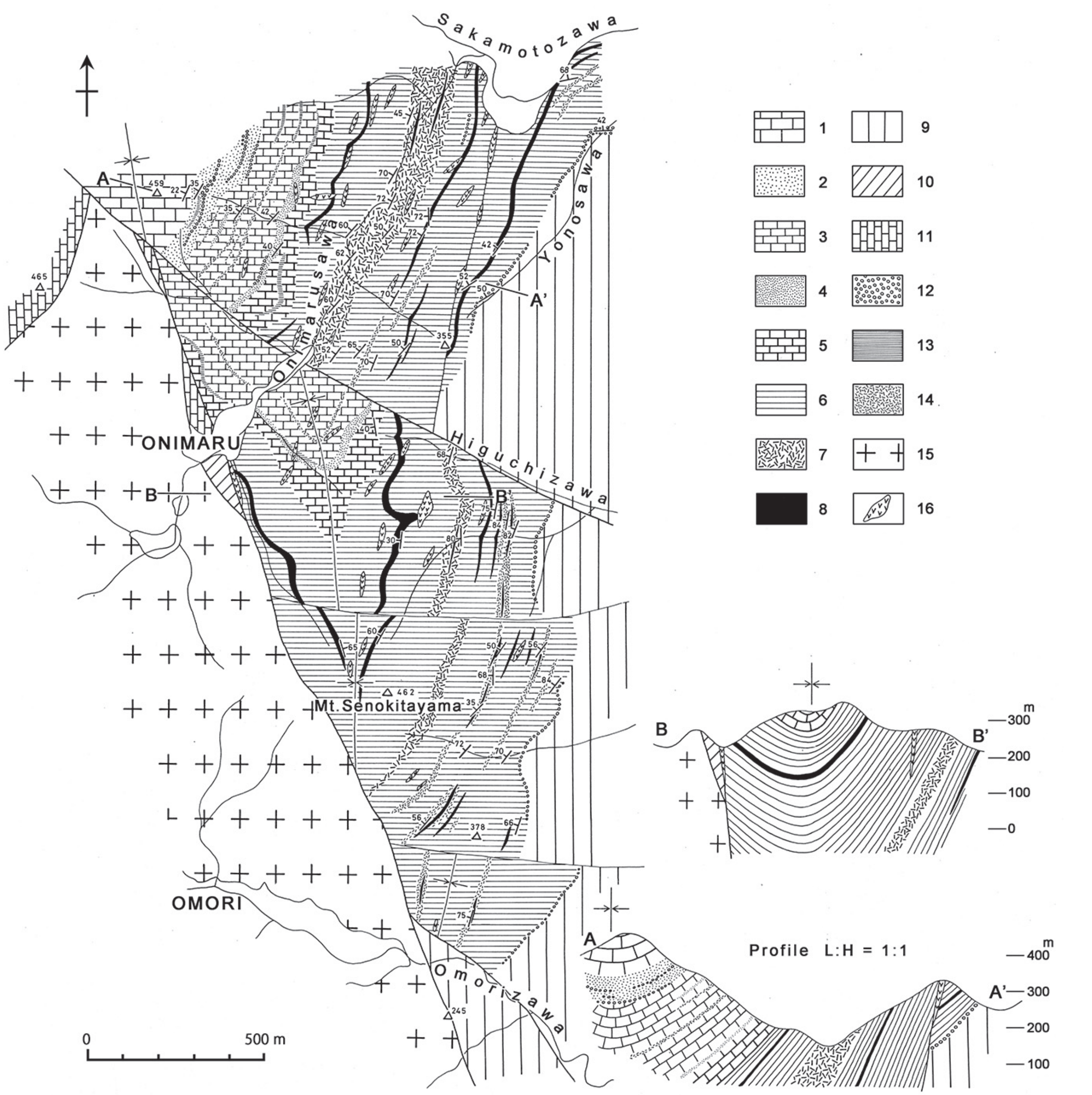


FIGURE 4. Geologic map of the Hikoroichi area (after Tazawa, 1984b). 1, 2, Lower Permian Sakamotozawa Formation (1, limestone; 2, sandstone); 3, 4, upper Carboniferous Nagaiwa Formation (3, limestone; 4, sandstone); 5, limestone of the lower Carboniferous Onimaru Formation; 6–8, lower Carboniferous Hikoroichi Formation (6, sandstone and shale; 7, tuff of the HK3 Unit; 8, limestone); 9, Middle Devonian Nakazato Formation; 10, Lower Devonian Ono Formation; 11, Silurian Kawauchi Formation; 12, conglomerate of the Hikoroichi, Nagaiwa and Sakamotozawa Formations; 13, shale of the Onimaru, Nagaiwa and Sakamotozawa Formations; 14, tuff of the HK1 and HK2 units of the Hikoroichi Formation and the Nagaiwa Formation; 15, granitic rocks of the Hikami Granite; 16, dyke rocks.

Minato, 1951, *Torynifer asiatica* Besnossova in Besnossova et al., 1962, *Syringothyris sibirica* Sokolskaya in Sarytcheva et al., 1963, *Pseudosyrinx* cf. *missouriensis* Weller, 1914, *Dimegelasma* sp., *Punctospirifer plicatosulcatus* Glenister, 1955, *P. gigantiformis* Lee and Gu in Lee et al., 1980, *P. iwatensis* sp. nov., *Punctospirifer* sp. and *Beecheria khalfini* Besnossova in Sarytcheva et al., 1963.

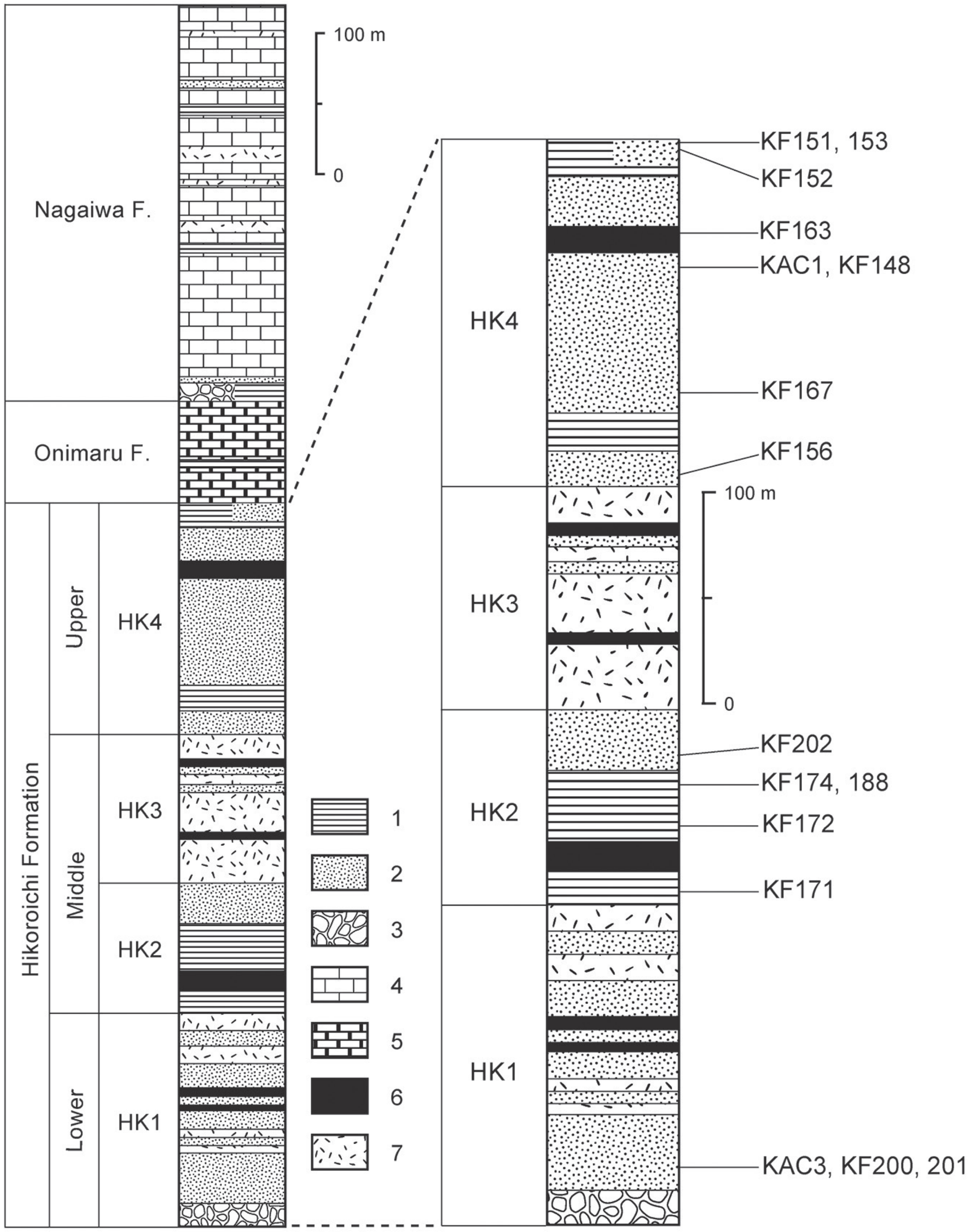


FIGURE 5. Generalized columnar section of the Carboniferous formations in the Hikoroichi area, showing the fossil horizons in the HK1, HK2 and HK4 units in the Hikoroichi Formation (modified and adapted from Tazawa, 1984b). 1, Shale; 2, sandstone; 3, conglomerate; 4, limestone (Nagaiwa Formation); 5, limestone (Onimaru Formation); 6, limestone (Hikoroichi Formation); 7, tuff.

**HK1 assemblage (late Tournaisian)**

The HK1 assemblage includes 18 species in 16 genera: *Leptagonia analoga*, *Plicochonetes* sp., *Tolmatchoffia robusta*, *Marginatia burlingtonensis*, *M. magna*, *Ovatia* sp., *Schizophoria resupinata*, *Rhynchopora* sp., *Cleiothyridina harkeri*, *Unispirifer mediocris*, *Acuminothyris keokuk*, *Brachythyris suborbicularis*, *Tylothyris laminosa*, *Kitakamithyris tyoanjiensis*, *K. hikoroitiensis*, *Syringothyris sibirica*, *Punctospirifer* sp. and *Beecheria khalfini*. Of these species, *Leptagonia analoga*, *Tolmatchoffia robusta* and *Acuminothyris keokuk* are abundant; *Marginatia magna*, *Unispirifer mediocris* and *Syringothyris sibirica* are common; and the others are rare (Fig. 6).

The stratigraphic distributions of the brachiopod species

| Species \ Lithological units, Localities | HK1 | | | HK2 | | | | | HK4 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | KAC3 | KF200 | KF201 | KF171 | KF172 | KF174 | KF188 | KF202 | KF156 | KF167 | KAC1 | KF148 | KF163 | KF152 | KF151 | KF153 |
| *Leptagonia analoga* | | | A | | R | | | R | | | R | | | | | |
| *Rugosochonetes* cf. *hardrensis* | | | | | | | | R | | | | | | | | |
| *Plicochonetes* sp. | | | R | | | | | | | | | | | | | |
| *Leiochonetes onimarensis* | | | | | | | | A | | | | | | | | |
| *Argentiproductus margaritaceus* | | | | | | | | | | | R | | | | | |
| *Tolmatchoffia robusta* | | | A | | | | | A | | | | | | | | |
| *Marginatia burlingtonensis* | | | R | R | C | C | C | A | | | | | | | | |
| *Marginatia magna* | R | | C | | | | | | | | | | | | | |
| *Echinoconchus punctatus* | | | | | | | | C | | | | | | | | |
| *Karavankina jizodoensis* | | | | | | | | | | R | | | | | | |
| *Pustula pustulosa* | | | | | | | | | | | | | | R | | |
| *Ovatia laevicosta* | | | | | | | R | R | | | | | | | | |
| *Ovatia* cf. *prolata* | | | | | | | | | | | R | | | | | |
| *Ovatia* sp. | | | R | | | | | | | | | | | | | |
| *Linoprotonia ashfellensis* | | | | | | | | A | | | | | | | | |
| *Linoprotonia hikoroichiensis* | | | | | | | | A | | | | | | | | |
| *Gigantoproductus crassiventer* | | | | | | | | C | | | | | | | | |
| *Gigantoproductus latiexpansus* | | | | | | | | C | | | | | | | | |
| *Orthotetes keokuk* | | | | | | | | C | | R | | | | | | |
| *Rhipidomella michelini* | | | | | | | | C | | | | | C | | | |
| *Schizophoria resupinata* | | R | R | | | | C | | | R | A | | | | | |
| *Rhynchopora* sp. | | | R | | | | | | | | | | | | | |
| *Rotaia hikoroichiensis* | | | | | | | | R | R | | | | | | | |
| *Actinoconchus expansus* | | | | | | | | C | | | | | | | | |
| *Actinoconchus paradoxus* | | | | | | | | R | | | | | | | | |
| *Lamellosathyris qaidamensis* | | | | | | | | A | | | | | | | | |
| *Cleiothyridina harkeri* | | R | | | | | | | | | | | | | | |
| *Cleiothyridina* sp. | | | | | | | | | | R | | | | | | |
| *Hustedia* sp. | | | | | | | | R | | | | | | | | |
| *Spirifer liangchowensis* | | | | | | | | | | | | | | | R | |
| *Spirifer karagai* | | | | | | | | C | | | | | | | | |
| *Unispirifer striatoconvolutus* | | | | | | | | A | | | | | | | | |
| *Unispirifer mediocris* | | | C | | | | | | | | | | | | | |
| *Unispirifer kozuboensis* | | | | | | | | A | | | | | | | | |
| *Angiospirifer bisulcatus* | | | | | | | | | | | | | | | | R |
| *Tegulocrea incerta* | | | | | | | | A | | | | | | | | |
| *Acuminothyris triangularis* | | | | | | | | R | | | | | | | | |
| *Acuminothyris keokuk* | | | A | | | | | | | | | | | | | |
| *Brachythyris suborbicularis* | | | R | | | | | | | | | | | | | |
| *Tylothyris laminosa* | R | | | | | | | | | | | | | | | |
| *Kitakamithyris tyoanjiensis* | | R | R | | | | | | | | | | | | | |
| *Kitakamithyris hikoroitiensis* | | | R | | | | R | | | | | | | | | |
| *Torynifer asiatica* | | | | | | | | | | | C | | | | | |
| *Syringothyris sibirica* | R | | C | | | | | | | | | | | | | |
| *Pseudosyrinx* cf. *missouriensis* | | | | | | | | R | | | | | | | | |
| *Dimegelasma* sp. | | | | | | | | | | | | | R | | | |
| *Punctospirifer plicatosulcatus* | | | | | | | | R | | | | | | | | |
| *Punctospirifer gigantiformis* | | | | | | | | R | | | | | | | | |
| *Punctospirifer iwatensis* | | | | | | | | | | | | R | | | | |
| *Punctospirifer* sp. | | R | R | | | | | | | | | | | | | |
| *Beecheria khalfini* | | R | | | | | | | | | | | | | | |

FIGURE 6. Occurrence of brachiopod species from the Hikoroichi Formation in the Hikoroichi area, South Kitakami Belt. A, abundant; C, common; R, rare.

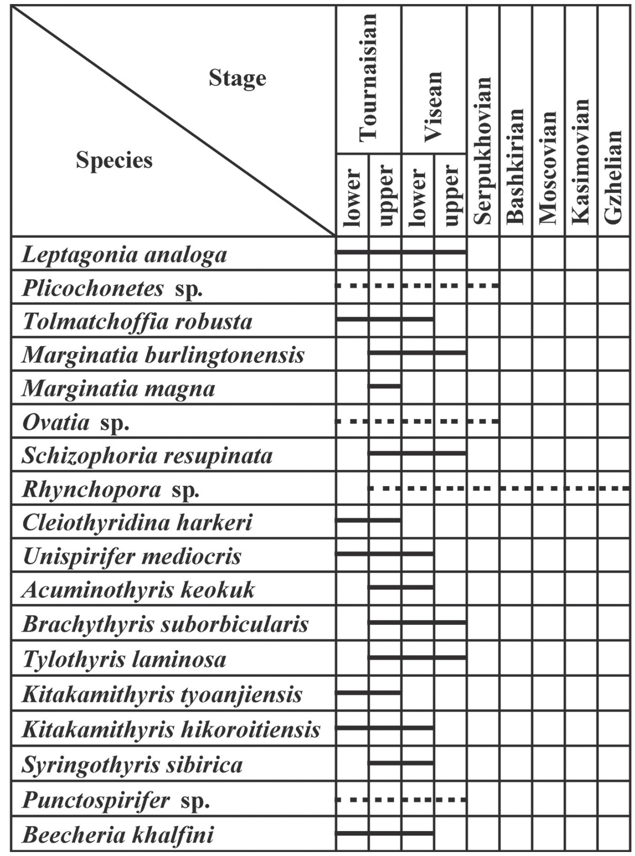


FIGURE 7. Stratigraphic distributions of brachiopod species of the HK1 assemblage in the Hikoroichi fauna. Broken lines show those of the genera.

of the HK1 assemblage are summarized in Fig. 7. Of the brachiopods listed above, *Marginatia magna* is known only from the upper Tournaisian, *Cleiothyridina harkeri* is known from the lower–upper Tournaisian, and *Kitakamithyris tyoanjiensis* has a range of upper Famennian–upper Tournaisian. In contrast, *Acuminothyris keokuk* and *Syringothyris sibirica* are known from the upper Tournaisian–lower Visean, four species (*Marginatia burlingtonensis*, *Schizophoria resupinata*, *Brachythyris suborbicularis* and *Tylothyris laminosa*) occur in the upper Tournaisian–upper Visean, three species (*Tolmatchoffia robusta*, *Unispirifer mediocris* and *Beecheria khalfini*) range from the lower Tournaisian–lower Visean, and *Kitakamithyris hikoroitiensis* has a range of upper Fammenian–lower Visean. *Leptagonia analoga* is a long-ranging species, known from the lower Tournaisian to the upper Visean. At the generic level, *Plicochonetes* is known from the lower Tournaisian–Serpukhovian (Racheboeuf, 2000), *Ovatia* ranges from the lower Tournaisian to the Serpukhovian (Brunton et al., 2000), *Rhynchopora* is known from the upper Tournaisian–Gzhelian (Savage, 2002), and *Punctospirifer* is known from the upper Famennian to the upper Visean (Carter, 2006b). In summary, the age of the HK1 assemblage is identified as late Tournaisian. Thus the lower part of the Hikoroichi Formation (HK1 Unit) is correlated with the upper Tournaisian.

The geographic distributions of the brachiopod species of the HK1 assemblgae are summarized in Figs. 8 and 9. Among the 18 species of the HK1 assemblage, seven species also occur in central Russia (Kuznetsk Basin); six species also occur in Kazakhstan; five species also occur in the USA (Missouri), central Russia (southern Urals) and northwestern China (Xinjiang); four species also occur in northern Russia (Verkhoyansk Range); and three species also occur in southwestern Japan (Akiyoshi

| Stage / Species | Japan | | | USA | | | | | | | | | Canada | N. Russia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. South Kitakami Belt | 2. Kanto Mountains | 3. Akiyoshi Belt | 4. Indiana | 5. Illinois | 6. Iowa | 7. Missouri | 8. Arkansas | 9. Oklahoma | 10. Idaho | 11. Utah | 12. New Mexico | 13. Alberta | 14. Verkhoyansk Range | 15. Taimyr Peninsula | 16. Novaya Zemlya | 17. Pechora Basin |
| *Leptagonia analoga* | + | | + | | + | + | + | | + | | + | + | + | + | | | + |
| *Plicochonetes* sp. | + | | | | | | | | | | | | | | | | |
| *Tolmatchoffia robusta* | + | | | | | | | | | | | | | | | | |
| *Marginatia burlingtonensis* | + | | + | | + | + | | + | | | | | + | | | | |
| *Marginatia magna* | + | | | | | | + | | + | | | | | | | | |
| *Ovatia* sp. | + | | | | | | | | | | | | | | | | |
| *Schizophoria resupinata* | + | + | + | | | | | | | + | | | | + | + | + | + |
| *Rhynchopora* sp. | + | | | | | | | | | | | | | | | | |
| *Cleiothyridina harkeri* | + | | | | | | | | | | | | + | | | | |
| *Unispirifer mediocris* | + | | | | | | + | | | | | | | + | | | |
| *Acuminothyris keokuk* | + | | | | | | + | | | | | | | | | | |
| *Brachythyris suborbicularis* | + | | | + | | + | + | | | | | | | + | | | |
| *Tylothyris laminosa* | + | | | | | | | | | | | | | | | | |
| *Kitakamithyris tyoanjiensis* | + | | | | | | | | | | | | | | | | |
| *Kitakamithyris hikoroitiensis* | + | | | | | | | | | | | | | | | | |
| *Syringothyris sibirica* | + | | | | | | | | | | | | | | | | |
| *Punctospirifer* sp. | + | | | | | | | | | | | | | | | | |
| *Beecheria khalfini* | + | | | | | | | | | | | | | | | | |

| Stage / Species | N. Russia | UK | | | | | | | | W. Russia | | | | | C. Russia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18. Northern Urals | 19. England | 20. Wales | 21. Isle of Man | 22. Northern Ireland | 23. Poland | 24. Germany | 25. Belgium | 26. Spain | 27. Moscow Basin | 28. Donetz Basin | 29. Turkey | 30. Iran | 31. Afghanistan | 32. Western Urals | 33. Southern Urals |
| *Leptagonia analoga* | | + | | + | + | | + | + | | | + | + | + | | | + |
| *Plicochonetes* sp. | | | | | | | | | | | | | | | | |
| *Tolmatchoffia robusta* | | | | | | | | | | | | | | | | |
| *Marginatia burlingtonensis* | | | | | | | | | | | | + | | | | + |
| *Marginatia magna* | | | | | | | | | | | | | | | | + |
| *Ovatia* sp. | | | | | | | | | | | | | | | | |
| *Schizophoria resupinata* | | + | + | + | | + | | + | + | + | + | | | | | + |
| *Rhynchopora* sp. | | | | | | | | | | | | | | | | |
| *Cleiothyridina harkeri* | | | | | | | | | | | | | | | | |
| *Unispirifer mediocris* | + | | | | | | | | | | | | | | | |
| *Acuminothyris keokuk* | | | | | | | | | | | | | | | | |
| *Brachythyris suborbicularis* | | | | | | | | | | | | | | | + | + |
| *Tylothyris laminosa* | | + | | | + | | | + | | | | | | + | + | |
| *Kitakamithyris tyoanjiensis* | | | | | | | | | | | | | | | | |
| *Kitakamithyris hikoroitiensis* | | | | | | | | | | | | | | | | |
| *Syringothyris sibirica* | | | | | | | | | | | | | | | | |
| *Punctospirifer* sp. | | | | | | | | | | | | | | | | |
| *Beecheria khalfini* | | | | | | | | | | | | | | | | |

| Stage / Species | C. Russia | | | | NW China | | N. China | | NE China | CS China | | | SW China | | Australia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 34. Kuznetsk Basin | 35. Kazakhstan | 36. Uzbekistan | 37. Kyrgyzstan | 38. Xinjiang | 39. Gansu | 40. Shaanxi | 41. Inner Mongolia | 42. Liaoning | 43. Hubei | 44. Guangdong | 45. Guangxi | 46. Guizhou | 47. Yunnan | 48. W. Australia | 49. E. Australia |
| *Leptagonia analoga* | + | + | | | + | + | | | | + | + | + | | + | + | + |
| *Plicochonetes* sp. | | | | | | | | | | | | | | | | |
| *Tolmatchoffia robusta* | + | | | + | + | | | | | | | | | | | |
| *Marginatia burlingtonensis* | + | + | | + | | | | | + | | | | | | | |
| *Marginatia magna* | | | | | | | | | | | | | | | | |
| *Ovatia* sp. | | | | | | | | | | | | | | | | |
| *Schizophoria resupinata* | + | + | + | | + | | + | + | | | | | + | + | | |
| *Rhynchopora* sp. | | | | | | | | | | | | | | | | |
| *Cleiothyridina harkeri* | | | | | | | | | | | | | | | | |
| *Unispirifer mediocris* | + | + | | | | | | | | | | | | | | |
| *Acuminothyris keokuk* | | | | | + | | | | | | | | | | | |
| *Brachythyris suborbicularis* | | + | | | | | | | | | | | | | | |
| *Tylothyris laminosa* | | + | | | | | | | | | | | + | | | |
| *Kitakamithyris tyoanjiensis* | | | | | | | | | | | | | | | | |
| *Kitakamithyris hikoroitiensis* | | | | | | | | | | | | | | | | |
| *Syringothyris sibirica* | + | | | | | | | | | | | | | | | |
| *Punctospirifer* sp. | | | | | | | | | | | | | | | | |
| *Beecheria khalfini* | + | | | | + | | | | | | | | | | | |

FIGURE 8. Geographic distributions of brachiopod species of the HK1 assemblage in the Hikoroichi fauna.

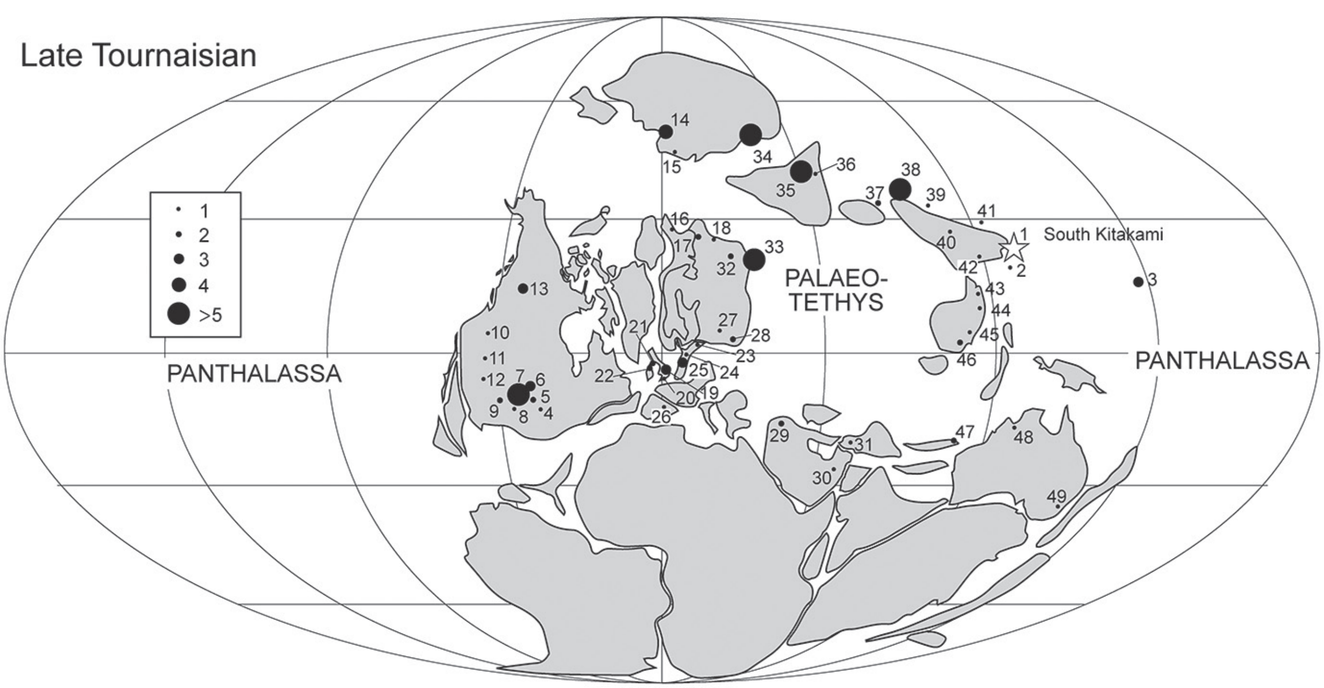


FIGURE 9. Late Tournaisian reconstruction map of the world (adapted from Qiao and Shen, 2014), showing the geographic distributions of brachiopod species of the HK1 assemblage in the Hikoroichi fauna. Solid circles indicate numbers of brachiopod species listed in the HK1 assemblage. Station numbers are same as in Fig. 8.

Belt), the USA (Iowa), Canada (Alberta), the UK (England) and Belgium. In summary, the HK1 assemblage has a close affinity with the early Carboniferous (Mississippian) brachiopod faunas of North America, western Europe, northern and central Russia, Kazakhstan and northwestern China. Thus, the HK1 assemblage is allied with those of the North China Province of Yang (1983), which covered northwestern–northeastern China in early Carboniferous, and is characterized by the Boreal elements such as *Syringothyris*, *Pseudosyrinx*, *Rotaia*, *Grandispirifer* and *Tolmatchoffia*, but lacks the South China (Tethyan) elements such as *Yanguania*, *Eochoristites* and *Martiniella*. According to Yang (1983), the faunas of the North China Province are essentially similar to those of northeastern Siberia and North America.

**HK2 assemblage (early Visean)**

The HK2 assemblage includes 28 species in 23 genera: *Leptagonia analoga*, *Rugosochonetes* cf. *hardrensis*, *Leiochonetes onimarensis*, *Tolmatchoffia robusta*, *Marginatia burlingtonensis*, *Echinoconchus punctatus*, *Ovatia laevicosta*, *Linoprotonia ashfellensis*, *L. hikoroichiensis*, *Gigantoproductus crassiventer*, *G. latiexpansus*, *Orthotetes keokuk*, *Rhipidomella michelini*, *Schizophoria resupinata*, *Rotaia hikoroichiensis*, *Actinoconchus expansus*, *A. paradoxus*, *Lamellosathyris qaidamensis*, *Hustedia* sp., *Spirifer karagai*, *Unispirifer striatoconvolutus*, *U. kozuboensis*, *Tegulocrea incerta*, *Acuminothyris triangularis*, *Kitakamithyris hikoroitiensis*, *Pseudosyrinx* cf. *missouriensis*, *Punctospirifer plicatosulcatus* and *P. gigantiformis*. Of these, *Leiochonetes onimarensis*, *Tolmatchoffia robusta*, *Marginatia burlingtonensis*, *Linoprotonia ashfellensis*, *L. hikoroichiensis*, *Lamellosathyris qaidamensis*, *Unispirifer striatoconvolutus*, *U. kozuboensis* and *Tegulocrea incerta* are abundant; *Echinoconchus punctatus*, *Gigantoproductus crassiventer*, *G. latiexpansus*, *Orthotetes keokuk*, *Rhipidomella michelini*, *Schizophoria repupinata*, *Actinoconchus expansus* and *Spirifer karagai* are common; and the others are rare (Fig. 6).

The stratigraphic distributions of the brachiopod species of the HK2 assemblage are summarized in Fig. 10. Of the brachiopods listed above, *Linoprotonia hikoroichiensis* and *Actinoconchus paradoxus* are known only from the lower Visean, five species (*Ovatia laevicosta*, *Lamellosathyris qaidamensis*, *Unispirifer kozuboensis*, *Tegulocrea incerta* and *Acuminothyris triangularis*) are known from the upper Tournaisian–lower Visean, *Tolmatchoffia robusta* and *Punctospirifer plicatosulcatus* are known from the lower Tournaisian–lower Visean, and *Kitakamithyris hikoroitiensis* is known from the upper Famennian–lower Visean. In contrast, five species (*Linoprotonia ashfellensis*, *Gigantoproductus crassiventer*, *Rotaia hikoroichiensis*, *Spirifer karagai* and *Punctospirifer gigantiformis*) are known from the lower–upper Visean, and *Gigantoproductus latiexpansus* and *Actinoconchus expansus* are known from the lower Visean–Serpukhovian. Three species are long-ranging species: *Leptagonia analoga* ranges from the lower Tournaisian to the upper Visean, *Echinoconchus punctatus* ranges from the upper Tournaisian to the Gzhelian, and *Rhipidomela michelini* ranges from the upper Tournaisian to the Bashkirian. At the generic level, *Rugosochonetes* has a long range from Tournaisian to Gzhelian (Racheboeuf, 2000), *Leiochonetes* is known from the upper Tournaisian–upper Visean (Carter, 1967; Roberts, 1976), *Hustedia* is known from the Tournaisian–Changhsingian (Alvarez and Rong, 2002b), and *Pseudosyrinx* is known from the upper Tournaisian–lower Visean (Carter, 2006a). In summary, the age of the HK2 assemblage is identified as early Visean. Thus, the middle part of the Hikoroichi Formation (HK2 Unit) is correlated with the lower Visean.

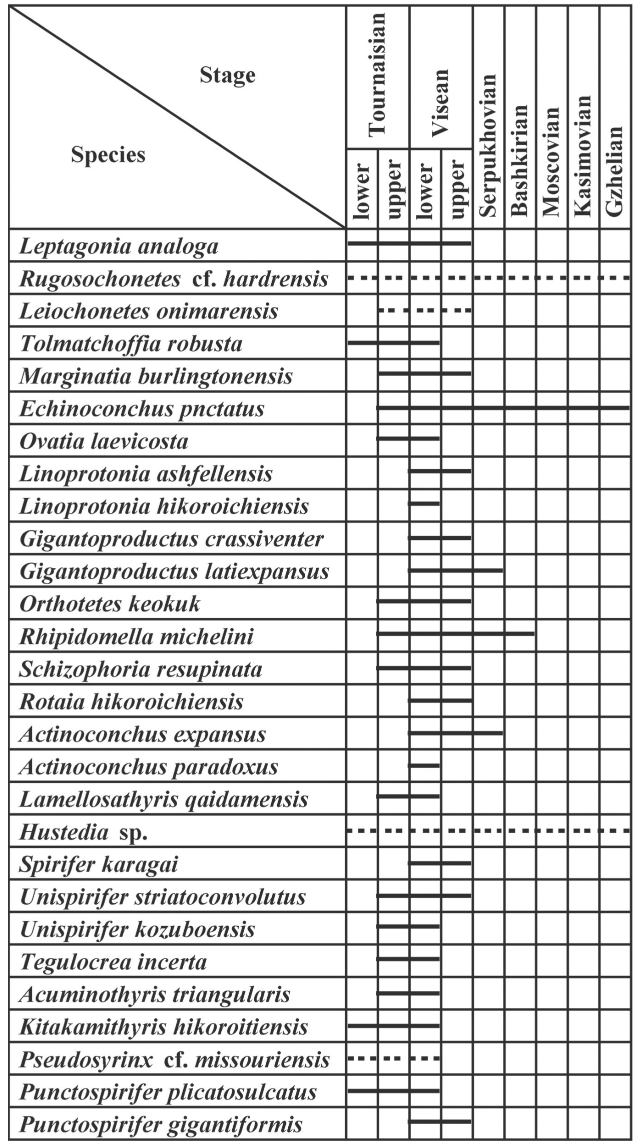

FIGURE 10. Stratigraphic distributions of brachiopod species of the HK2 assemblage in the Hikoroichi fauna. Broken lines show those of the genera.

The geographic distributions of the brachiopod species of the HK2 assemblage are summarized in Figs. 11 and 12. Among the 28 species of the HK2 assemblage, seven species also occur in the UK (England) and Kazakhstan; six species also occur in

| Species \ Region | Japan | | | USA | | | | | | | | | | Canada | | N. Russia | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. South Kitakami Belt | 2. Kanto Mountains | 3. Akiyoshi Belt | 4. Ohio | 5. Indiana | 6. Illinois | 7. Iowa | 8. Missouri | 9. Oklahoma | 10. Utah | 11. Idaho | 12. New Mexico | 13. Arizona | 14. Nova Scotia | 15. Alberta | 16. Verkhoyansk Range | 17. Kolyma | 18. Taimyr Peninsula | 19. Novaya Zemlya | 20. Pechora Basin |
| *Leptagonia analoga* | + | | + | | | + | + | + | + | + | | + | | | + | + | | | | + |
| *Rugosochonetes* cf. *hardrensis* | + | | | | | | | | | | | | | | | | | | | |
| *Leiochonetes onimarensis* | + | | | | | | | | | | | | | | | | | | | |
| *Tolmatchoffia robusta* | + | | | | | | | | | | | | | | | | | | | |
| *Marginatia burlingtonensis* | + | | + | | | + | + | | | | | | + | | + | | | | | |
| *Echinoconchus pnctatus* | + | | | | | | | | | | | | | | | + | | + | | |
| *Ovatia laevicosta* | + | | | | | | + | | + | | | | | | | | | | | |
| *Linoprotonia ashfellensis* | + | | | | | | | | | | | | | | | | | | | |
| *Linoprotonia hikoroichiensis* | + | | | | | | | | | | | | | | | | | | | |
| *Gigantoproductus crassiventer* | + | | | | | | | | | | | | | + | | | | | | |
| *Gigantoproductus latiexpansus* | + | | | | | | | | | | | | | | | | | | | |
| *Orthotetes keokuk* | + | | | | | | + | + | | | | + | + | | | + | | | | |
| *Rhipidomella michelini* | + | | | | | | | | | | | | | | | | | + | | + |
| *Schizophoria resupinata* | + | + | + | | | | | | | | + | | | | | + | | + | + | + |
| *Rotaia hikoroichiensis* | + | | | | | | | | | | | | | | | | | | | |
| *Actinoconchus expansus* | + | | | | | | | | | | | | | | | | + | | | |
| *Actinoconchus paradoxus* | + | | | | | | | | | | | | | | | | | | | |
| *Lamellosathyris qaidamensis* | + | | | + | + | | | + | + | | | | | | | | | | | |
| *Hustedia* sp. | + | | | | | | | | | | | | | | | | | | | |
| *Spirifer karagai* | + | | | | | | | | | | | | | | | | | | | |
| *Unispirifer striatoconvolutus* | + | | | | | | | | | | | | | | | | | | | |
| *Unispirifer kozuboensis* | + | | | | | | | | | | | | | | | | | | | |
| *Tegulocrea incerta* | + | | | | | | + | | + | | | | | | | | | | | |
| *Acuminothyris triangularis* | + | | | | | | | | | | | | | | | | | | | |
| *Kitakamithyris hikoroitiensis* | + | | | | | | | | | | | | | | | | | | | |
| *Pseudosyrinx* cf. *missouriensis* | + | | | | | | | | | | | | | | | | | | | |
| *Punctospirifer plicatosulcatus* | + | | | | | | | | | | | | | | | | | | | |
| *Punctospirifer gigantiformis* | + | | | | | | | | | | | | | | | | | | | |

| Species \ Region | N. Russia | UK | | | | | | | | | | | W. Russia | | | | C. Russia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 21. Northern Urals | 22. Scotland | 23. England | 24. Wales | 25. Isle of Man | 26. Northern Ireland | 27. Ireland | 28. Poland | 29. Germany | 30. Belgium | 31. France | 32. Spain | 33. Moscow Basin | 34. Donetz Basin | 35. Turkey | 36. Iran | 37. Western Urals | 38. Southern Urals | 39. Kuznetsk Basin | 40. Kazakhstan |
| *Leptagonia analoga* | | | + | | + | + | | | + | + | | | | + | + | + | | + | + | + |
| *Rugosochonetes* cf. *hardrensis* | | | | | | | | | | | | | | | | | | | | |
| *Leiochonetes onimarensis* | | | | | | | | | | | | | | | | | | | | |
| *Tolmatchoffia robusta* | | | | | | | | | | | | | | | | | | | + | |
| *Marginatia burlingtonensis* | | | | | | | | | | | | | | | | | | + | + | + |
| *Echinoconchus pnctatus* | + | + | + | + | | | | | + | + | | + | + | | | | | + | | |
| *Ovatia laevicosta* | | | | | | | | | | | | | | | | | | | + | |
| *Linoprotonia ashfellensis* | | | + | | | | | | | | | | | | | | | | | |
| *Linoprotonia hikoroichiensis* | | | | | | | | | | | | | | | | | | | | |
| *Gigantoproductus crassiventer* | | | + | | | | | | | | | | | | | | | | | |
| *Gigantoproductus latiexpansus* | | | | | | | | | | | | | + | | | | | | | |
| *Orthotetes keokuk* | | | | | | | | | | | | | | | | | | | | + |
| *Rhipidomella michelini* | | | + | + | | + | + | + | | + | + | + | + | + | | + | | + | | + |
| *Schizophoria resupinata* | | | + | + | + | | | + | | + | | + | + | + | | | | + | + | + |
| *Rotaia hikoroichiensis* | | | | | | | | | | | | | | | | | | | | |
| *Actinoconchus expansus* | | | + | | | | | | | | | | | + | | | + | | | |
| *Actinoconchus paradoxus* | | | | | | | + | | | | | | | | | | | | | |
| *Lamellosathyris qaidamensis* | | | | | | | | | | | | | | | | | | | | + |
| *Hustedia* sp. | | | | | | | | | | | | | | | | | | | | |
| *Spirifer karagai* | | | | | | | | | | | | | | | | | | | | + |
| *Unispirifer striatoconvolutus* | | | | | | | | | | | | | | | | | | | | |
| *Unispirifer kozuboensis* | | | | | | | | | | | | | | | | | | | | |
| *Tegulocrea incerta* | | | | | | | | | | | | | | | | | | | | |
| *Acuminothyris triangularis* | | | | | | | | | | | | | | | | | | | | |
| *Kitakamithyris hikoroitiensis* | | | | | | | | | | | | | | | | | | | | |
| *Pseudosyrinx* cf. *missouriensis* | | | | | | | | | | | | | | | | | | | | |
| *Punctospirifer plicatosulcatus* | | | | | | | | | | | | | | | | | | | | |
| *Punctospirifer gigantiformis* | | | | | | | | | | | | | | | | | | | | |

| Species \ Region | | | NW China | | | | | N. China | | NE China | | CS China | | | SW China | | Australia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 41. Uzbekistan | 42. Kyrgyzstan | 43. Xinjiang | 44. Qinghai | 45. Gansu | 46. Ningxia | 47. Shaanxi | 48. Inner Mongolia | 49. Shanxi | 50. Jilin | 51. Liaonin | 52. Hubei | 53. Guangdong | 54. Guangxi | 55. Guizhou | 56. Yunnan | 57. W. Australia | 58. E. Australia |
| *Leptagonia analoga* | | | + | | + | | | | | | | + | + | + | | + | + | + |
| *Rugosochonetes* cf. *hardrensis* | | | | | | | | | | | | | | | | | | |
| *Leiochonetes onimarensis* | | | | | | | | | | | | | | | | | | |
| *Tolmatchoffia robusta* | | + | + | | | | | | | | | | | | | | | |
| *Marginatia burlingtonensis* | | + | | | | | | | | | + | | | | | | | |
| *Echinoconchus pnctatus* | | + | + | + | | | | | + | | | | | | | | | |
| *Ovatia laevicosta* | | | | | | | | | | | | | | | | | | |
| *Linoprotonia ashfellensis* | | | | | | | | | | | | | | | | | | |
| *Linoprotonia hikoroichiensis* | | | | | | | | | | | | | | | | | | |
| *Gigantoproductus crassiventer* | | | | | | | | | | | | | | | | | | |
| *Gigantoproductus latiexpansus* | | | | | | | | | | | | | | | | | | |
| *Orthotetes keokuk* | | | | | | | | | | | | | | | | | | |
| *Rhipidomella michelini* | + | | + | + | + | + | | | | | + | | | | + | + | | |
| *Schizophoria resupinata* | + | | + | | | | + | + | | | | | | | + | + | | |
| *Rotaia hikoroichiensis* | | | | | | | | | | | | | | | | | | |
| *Actinoconchus expansus* | | | | + | | | | | | | | | | | | | | |
| *Actinoconchus paradoxus* | | | | | | | | | | | | | | | | | | |
| *Lamellosathyris qaidamensis* | | | + | + | | | | | | | | | | | | | | |
| *Hustedia* sp. | | | | | | | | | | | | | | | | | | |
| *Spirifer karagai* | | | | | | | | | | | | | | | | | | |
| *Unispirifer striatoconvolutus* | | | | | | | | | | | | | | | | + | | + |
| *Unispirifer kozuboensis* | | | | | | | | | | | | | | | | | | |
| *Tegulocrea incerta* | | | | | | | | | | | | | | | | | | |
| *Acuminothyris triangularis* | | | | | | | | | | | | | | | | | | + |
| *Kitakamithyris hikoroitiensis* | | | | | | | | | | | | | | | | | | |
| *Pseudosyrinx* cf. *missouriensis* | | | | | | | | | | | | | | | | | | |
| *Punctospirifer plicatosulcatus* | | | | | | | | | | | | | | | | | + | |
| *Punctospirifer gigantiformis* | | | | | | | | | | + | | | | | | | | |

FIGURE 11. Geographic distributions of brachiopod species of the HK2 assemblage in the Hikoroichi fauna.

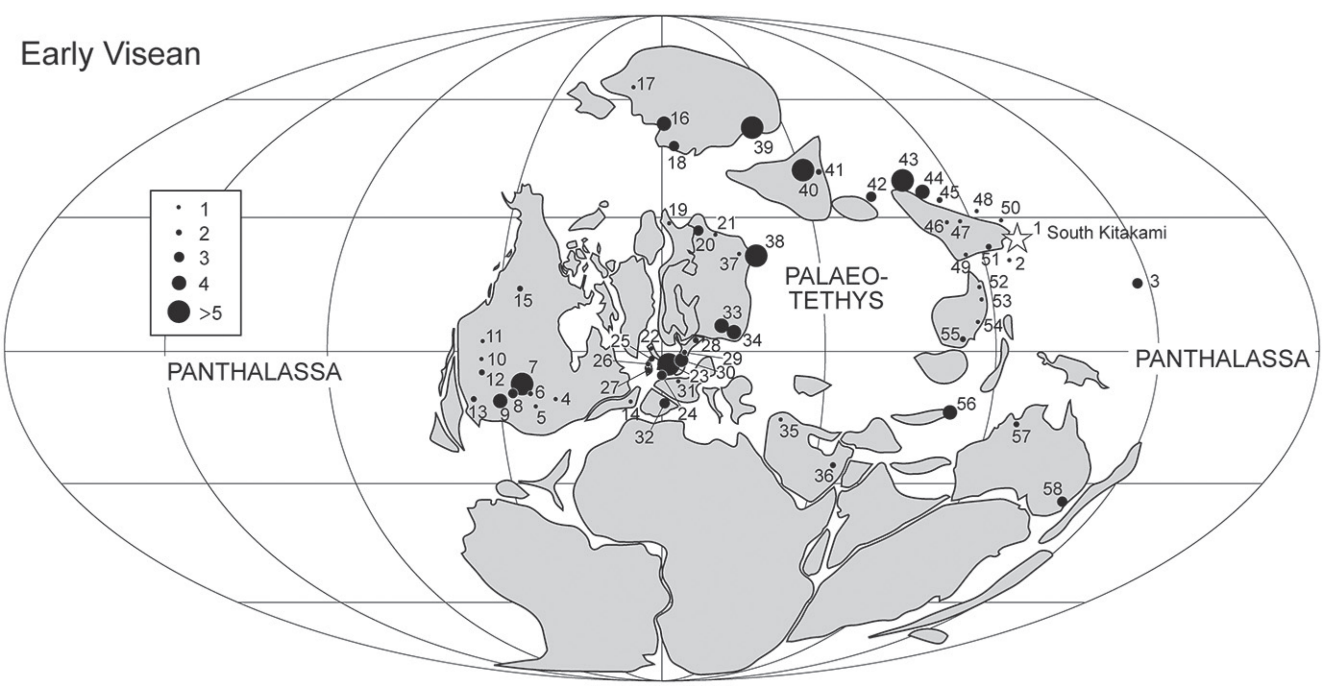


FIGURE 12. Early Visean reconstruction map of the world (adapted from Qiao and Shen, 2014), showing the geographic distributions of brachiopod species of the HK2 assemblage in the Hikoroichi fauna. Solid circles indicate numbers of brachiopod species listed in the HK2 assemblage. Station numbers are same as in Fig. 11.

northwestern China (Xinjiang); five species also occur in the USA (Iowa) and central Russia (southern Urals and Kuznetsk Basin); four species also occur in the USA (Oklahoma), Belgium, western Russia (Moscow Basin and Donetz Basin), northwestern China (Qinghai) and southwestern China (Yunnan); and three species also occur in southwestern Japan (Akiyoshi Belt), the USA (Missouri), northern Russia (Taimyr Peninsula and Pechora Basin), the UK (Wales), Spain, Kyrgyzstan and eastern Australia. In summary, the HK2 assemblage has a close affinity with the early Carboniferous (Mississippian) brachiopod faunas of North America, western Europe (England and Belgium), northern, western and central Russia, Kazakhstan and northwestern China (Xinjiang and Qinghai). Thus, the HK2 assemblage also is allied with those of the North China Province of Yang (1983).

**HK4 assemblage (late Visean)**

The HK4 assemblage includes 15 species in 15 genera: *Leptagonia analoga*, *Argentiproductus margaritaceus*, *Karavankina jizodoensis*, *Pustula pustulosa*, *Ovatia* cf. *prolata*, *Orthotetes keokuk*, *Rhipidomella michelini*, *Schizophoria resupinata*, *Rotaia hikoroichiensis*, *Cleiothyridina* sp., *Spirifer liangchowensis*, *Angiospirifer bisulcatus*, *Torynifer asiatica*, *Dimegelasma* sp. and *Punctospirifer iwatensis*. Of these species, *Schizophoria resupinata* is abundant; *Rhipidomella michilini* and *Torynifer asiatica* are common; and the other species are rare (Fig. 6).

The stratigraphic distributions of the brachiopod species of the HK4 assemblage are summarized in Fig. 13. Of the brachiopods listed above, *Orthotetes keokuk* and *Schizophoria resupinata* are known from the upper Tournaisian–upper Visean, *Rotaia hikoroichiensis* and *Spirifer liangchowensis* are known from the lower–upper Visean, and *Karavankina jizodoensis* is restricted to the upper Visean. In contrast, *Angiospirifer bisulcatus* is known from the upper Visean–Bashkirian, four species (*Argentiproductus margaritaceus*, *Pustula pustulosa*, *Rhipidomella michelini* and *Torynifer asiatica*) are long-ranging species, though within the lower Tournaisian–Bashkirian. At the generic level, *Ovatia* is known from the lower Tournaisian–Serpukhovian (Brunton et al., 2000), *Cleiothyridina* ranges from the Famennian to the Wuchiapingian (Alvarez and Rong, 2002a), *Dimegelasma* is known from the lower–upper Visean (Carter, 2006a), and *Punctospirifer* is known from the upper Famennian–upper Visean (Carter, 2006b). In summary, the age of the HK4 fauna is identified as late Visean. Thus, the upper part of the Hikoroichi Formation (HK4 Unit) is correlated with the upper Visean.

The geographic distributions of the brachiopod species of the HK4 assemblage are summarized in Figs. 14 and 15. Among the 15 species of the HK4 assemblage, six species also occur in the UK (England), Kazakhstan and northwestern China (Xinjiang); five species also occur in northern Russia (Pechora Basin), the UK (northern Ireland), Belgium, western Russia (Donetz Basin), central Russia (southern Urals) and Uzbekistan; four species also occur in northern Russia (Verkhoyansk Range), Germany and Poland; and three species also occur in northern Russia (Taimyr Peninsula), the UK (Wales and Isle of Man), western

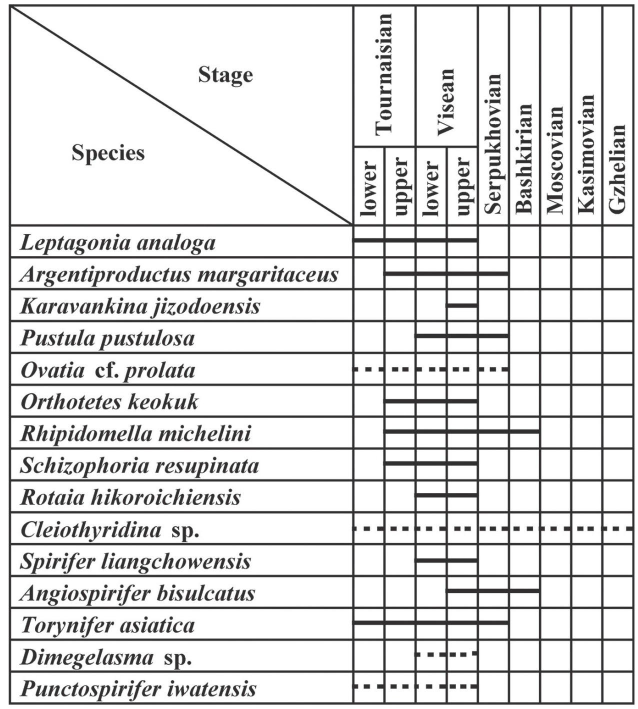


FIGURE 13. Stratigraphic distributions of brachiopod species of the HK4 assemblage in the Hikoroichi fauna. Broken lines show those of the genera.

Russia (Moscow Basin), central Russia (Kuznetsk Basin), Kyrgyzstan and northwestern China (Gansu). In summary, the HK4 assemblage has a close affinity with the early Carboniferous (Mississippian) brachiopod faunas of the UK, northern, western and central Russia, Kazakhstan, Uzbekistan and northwestern China. Thus, the HK4 assemblage also is allied with those of the North China Province of Yang (1983).

## CONCLUSIONS

In this study, an early Carboniferous (Mississippian) brachiopod fauna (Hikoroichi fauna: HK1, HK2 and HK4 assemblages), consisting of 51 species in 36 genera (including two new species, *Leiochonetes onimarensis* sp. nov. and *Punctospirifer iwatensis* sp. nov.) are described from the lower part (HK1 Unit), the middle part (HK2 Unit) and the upper part (HK4 Unit) of the Hikoroichi Formation in the Hikoroichi area, South Kitakami Belt, northeastern Japan. The HK1 assemblage, consisting of 18 species in 16 genera, indicates a late Tournaisian age; the HK2 assemblage, consisting of 28 species in 23 genera, indicates an early Visean age; and the HK4 assemblage, consisting of 15 species in 15 genera, indicates a late Visean age. Thus, the Hikoroichi Formation is correlated with the upper Tournaisian–upper Visean. In terms of palaeobiogeography, the HK1, HK2 and HK4 assemblages have close affinities with the early Carboniferous brachiopod faunas of North America (Missouri and Iowa), western Europe (England), northern Russia (Verkhoyansk Range), central Russia (southern Urals and Kuznetsk Basin),

| Region / Species | Japan | | | USA | | | | | | | | Canada | N. Russia | | | | UK | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1. South Kitakami Belt | 2. Kanto Mountains | 3. Akiyoshi Belt | 4. Illinois | 5. Iowa | 6. Missouri | 7. Oklahoma | 8. Utah | 9. Idaho | 10. New Mexico | 11. Arizona | 12. Alberta | 13. Verkhoyansk Range | 14. Taimyr Peninsula | 15. Novaya Zemlya | 16. Pechora Basin | 17. Scotland | 18. England | 19. Wales | 20. Isle of Man | 21. Northern Ireland | 22. Ireland | 23. Poland | 24. Germany | 25. Belgium | 26. France | 27. Spain |
| *Leptagonia analoga* | + | | + | + | + | + | + | + | | + | | + | + | | | + | | + | | + | + | | | + | + | | |
| *Argentiproductus margaritaceus* | + | | | | | | | | | | | | | | | + | | + | + | | + | | + | + | + | | |
| *Karavankina jizodoensis* | + | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pustula pustulosa* | + | | | | | | | | | | | | | | | + | | + | | | + | | | + | | | |
| *Ovatia* cf. *prolata* | + | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Orthotetes keokuk* | + | | | | + | + | | | | + | + | | + | | | | | | | | | | | | | | |
| *Rhipidomella michelini* | + | | | | | | | | | | | | | + | | + | | + | + | | + | + | + | | + | + | + |
| *Schizophoria resupinata* | + | + | + | | | | | | + | | | | + | + | + | + | | + | + | + | | | + | | + | | + |
| *Rotaia hikoroichiensis* | + | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cleiothyridina* sp. | + | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Spirifer liangchowensis* | + | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Angiospirifer bisulcatus* | + | | | | | | | | | | | | + | + | | | + | + | | + | + | | + | + | + | | |
| *Torynifer asiatica* | + | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Dimegelasma* sp. | + | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Punctospirifer iwatensis* | + | | | | | | | | | | | | | | | | | | | | | | | | | | |

| Region / Species | W. Russia | | | | | C. Russia | | | | | | | NW China | | | | | N. China | NE China | CS China | | | SW China | | | Australia | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 28. Moscow Basin | 29. Donetz Basin | 30. Turkey | 31. Iran | 32. Afghanistan | 33. Western Urals | 34. Southern Urals | 35. Kuznetsk Basin | 36. Zabaykal | 37. Kazakhstan | 38. Uzbekistan | 39. Kyrgyzstan | 40. Xinjiang | 41. Qinghai | 42. Gansu | 43. Ningxia | 44. Shaanxi | 45. Inner Mongolia | 46. Liaonin | 47. Hubei | 48. Guangdong | 49. Guangxi | 50. Guizhou | 51. Yunnan | 52. Tibet (Xizang) | 53. W. Australia | 54. E. Australia |
| *Leptagonia analoga* | | + | + | + | | | + | + | | | | | + | | + | | | | | + | + | + | | + | | + | + |
| *Argentiproductus margaritaceus* | + | + | | | | | + | | | + | + | + | | | | | | | | | | | + | | | + | |
| *Karavankina jizodoensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pustula pustulosa* | | | | | | + | + | | | | + | + | + | | | | | | | | | | | | | | |
| *Ovatia* cf. *prolata* | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Orthotetes keokuk* | | | | | | | | | | + | | | | | | | | | | | | | | | | | |
| *Rhipidomella michelini* | + | + | | + | | | + | | | + | + | | + | + | + | + | | + | + | | | | + | + | | | |
| *Schizophoria resupinata* | + | + | | | | | + | + | | + | + | | + | | | | + | + | | | | | + | + | | | |
| *Rotaia hikoroichiensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cleiothyridina* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Spirifer liangchowensis* | | | | | | | | | | | | | | | + | | | | | | | | | | | | |
| *Angiospirifer bisulcatus* | | + | | | | | | | | + | + | + | + | | | | | | | | | | | | | | + |
| *Torynifer asiatica* | | | | | + | | | + | + | + | | | + | | | | | | | | | | | | + | | |
| *Dimegelasma* sp. | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Punctospirifer iwatensis* | | | | | | | | | | | | | | | | | | | | | | | | | | | |

FIGURE 14. Geographic distributions of brachiopod species of the HK4 assemblage in the Hikoroichi fauna.

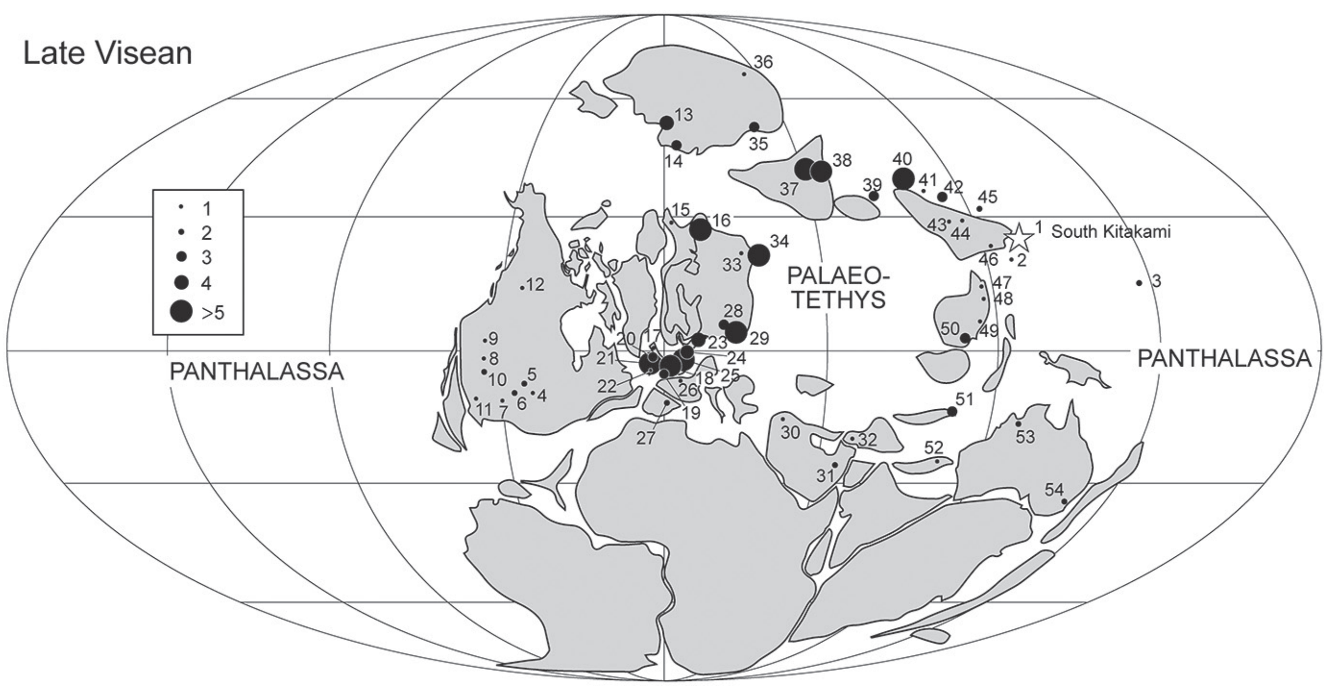


FIGURE 15. Late Visean reconstruction map of the world (adapted from Qiao and Shen, 2014), showing the geographic distributions of brachiopod species of the HK4 assemblage in the Hikoroichi fauna. Solid circles indicate numbers of brachiopod species listed in the HK4 assemblage. Station numbers are same as in Fig. 14.

Kazakhstan and northwestern China (Xinjiang). In other words, these assemblages are allied with those of the North China Province of Yang (1983). Thus, the South Kitakami region was probably the eastern extension of the province, and located east to the North China (Sino-Korea) block in the early Carboniferous.

## 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, b, 2002, 2006) and Selden (2007), with exception that classification of the

Productidina follows Waterhouse (2002).

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)
(Figs. 16B–F, 22A, B, 30A)

*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. 1–14; 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, 2017b, p. 333, fig. 6.1.

**Material.**—Fourteen specimens from localities KAC1, KF172, KF201 and KF202: (1) external and internal mould of a ventral valve, NU-B2122; (2) external moulds of two ventral valves, NU-B2081, 2082, (3) internal mould of a ventral valve, NU-B2123; (4) external and internal moulds of two dorsal valves, NU-B2125, 2126; (5) external moulds of six dorsal valves, NU-B2083, 2124, 2127–2129, 2239; and (6) internal moulds of two dorsal valves, NU-B2130, 2131.

**Description.**—Shell large in size for genus, transversely trapezoidal in outline, hinge equal to greatest width; length 34 mm, width 66 mm in the largest dorsal valve specimen (NU-B2127). Ventral valve gently convex in visceral disc, strongly geniculated, and followed by short trail; umbo small; sulcus absent. Dorsal valve flat to slightly concave in visceral disc, strongly geniculated, and followed by a short trail; fold absent; marginal ridge around visceral disc often developed in adult shell. External surface of both valves ornamented with fine rounded costellae and regular, slightly flexuous rugae; numbering 10–11 costellae in 5 mm at about midlength, and 16 –17 rugae in visceral disc of ventral valve. Ventral interior with strong teeth and large subcircular pseudospondylium, about one-third as long as length of disc. Dorsal interior with a bilobate cardinal process supported by low divergent socket ridges; adductor scars raised, pear-shaped, and divided by a long median septum extending for about two-fifths length of disc.

**Remarks.**—These specimens can be referred to *Leptagonia analoga* (Phillips, 1836), redescribed by Thomas (1971, p. 30, pl. 18, figs. 1–8, text-fig. 11) from the upper Tournaisian of the Bonaparte Gulf Basin, western Australia, in general shape, external ornament and internal structure of both valves, particularly, the large transversely trapezoidal shell, ornamented with numerous costellae and regular concentric rugae, and in having a prominent marginal ridge around visceral disc of dorsal valve and raised muscle field on both ventral and dorsal valves. Comparison with the other species of *Leptagonia* was fully discussed by Brand (1972).

**Occurrence.**—HK1, HK2 and HK4 units.

**Distribution.**—Lower Tournaisian–upper Visean: northeastern Japan (Hikoroichi, Yokota and Soma in the South Kitakami Belt), southwestern Japan (Hina in the Akiyoshi Belt), USA (Illinois, Iowa, Missouri, Oklahoma, Utah and New Mexico), western Canada (Alberta), northern Russia (Verkhoyansk Range and Pechora Basin), UK (England, lsle 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.

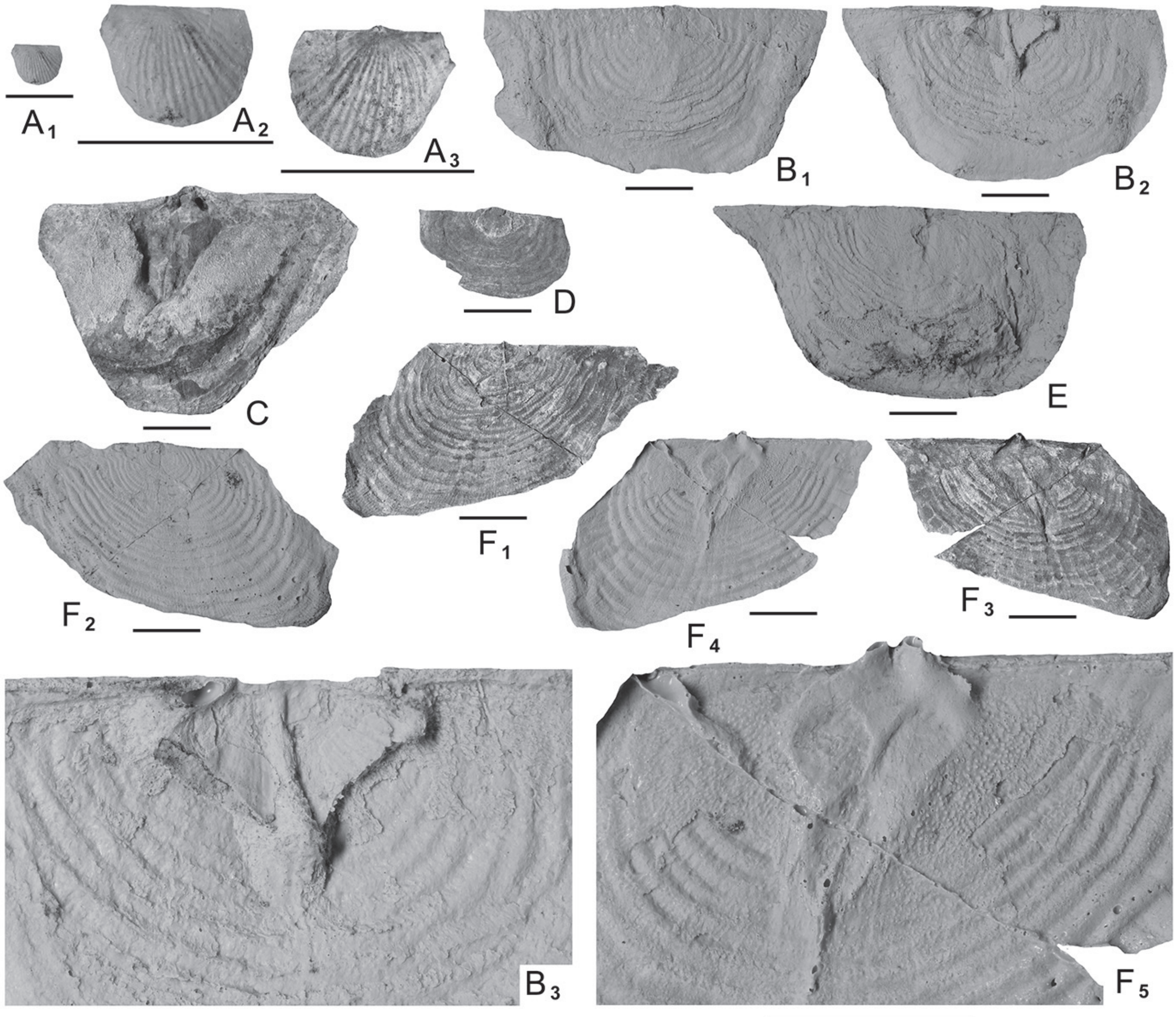


FIGURE 16. Brachiopods of the HK1 assemblage (1). **A,** *Plicochonetes* sp., external latex cast ($A_1$, $A_2$) and external mould ($A_3$) of ventral valve, NU-B2173; **B–F,** *Leptagonia analoga* (Phillips); **B,** external latex cast ($B_1$) and internal latex cast ($B_2$, $B_3$) of ventral valve, NU-B2122; **C,** internal mould of dorsal valve, NU-B2130; **D,** internal mould of ventral valve, NU-B2123; **E,** external latex cast of dorsal valve, NU-B2127; **F,** external mould ($F_1$), external latex cast ($F_2$), internal mould ($F_3$) and internal latex cast ($F_4$, $F_5$) of dorsal valve, NU-B2126. Scale bars represent 1 cm.

*Rugosochonetes* cf. *hardrensis* (Phillips, 1841)
(Fig. 22C)

cf. *Rugosochonetes hardrensis* (Phillips). Muir-Wood, 1962, p. 66–68, pl. 8, figs. 7–10, 13.

**Material.**—One specimen from locality KF202, external and internal moulds of a dorsal valve, NU-B2042.

**Remarks.**—The single dorsal valve specimen from the Onimaru quarry, Hikoroichi is safely assigned to the genus *Rugosochonetes* by the small (length 8 mm, width 8 mm), subquadrate and flat to slightly concave dorsal valve, ornamented with numerous capillae (numbering 6 in 1 mm at midlength of valve) and in having strong diverging socket ridges. The Hikoroichi species somewhat resembles *Rugosochonetes hardrensis* (Phillps, 1841), redescribed by Muir-Wood (1962, p. 66, pl. 8, figs. 7–10, 13) from the upper Visean of Yorkshire, England, in size, outline and external ornament of the dorsal valve. However accurate comparison is difficult for the poorly preserved material.

**Occurrence.**—HK2 Unit.

Subfamily PLICOCHONETINAE Sokolskaya, 1960
Genus *PLICOCHONETES* Paeckelmann, 1930

**Type species.**—*Chonetes buchianus* de Koninck, 1843.

*Plicochonetes* sp.
(Fig. 16A)

**Material.**—One specimen from locality KF201, external mould of a ventral valve, NU-B2173.

**Remarks.**—The single specimen from Hikoroichi is safely assigned to the genus *Plicochonetes* by the small, transverse and strongly convex ventral valve (length 7 mm, width 10 mm), with large ears and external ornament consisting of coarse costellae (numbering 6–7 in 3 mm at about midlength) and very fine growth lines. This specimen most resembles the shells, described by Litvinovich et al. (1975, p. 57, pl. 17, figs. 7, 8) as *Plicochonetes glenparkensis* (Weller, 1906), from the lower Tournaisian of central Kazakhstan, in having large ears on the ventral valve. The type species, *Plicochonetes buchianus* (de Koninck, 1843), refigured by Muir-Wood (1962, pl. 15, figs. 1–4), from the upper Visean and Serpukhovian of England, differs from the present species in the larger size and in having fewer and coarser costellae on the ventral valve.

**Occurrence.**—HK1 Unit.

Subfamily SVALBARDIINAE Archbold, 1982
Genus *LEIOCHONETES* Roberts, 1976

**Type species.**—*Leiochonetes salisburyensis* Roberts, 1976.

*Leiochonetes onimarensis* sp. nov.
(Fig. 22D–F)

**Etymology.**—Named after the fossil locality, Onimaru in the Hikoroichi-cho, Ofunato City, Iwate Prefecture.

**Material.**—Six specimens from locality KF202: (1) external and internal moulds of two ventral valves, NU-B2136 (holotype), 2137; (2) internal mould of a ventral valve, NU-B2138; and (3) external moulds of three dorsal valves, NU-B2139–2141.

**Diagnosis.**—Large-sized and moderately concavo-convex *Leiochonetes*, with blunt, acute cardinal extremities.

**Description.**—Shell large in size for genus, transversely semicircular in outline, with blunt, acute cardinal extremities, widest at hinge; length 11 mm, width 20 mm in the largest dorsal valve specimen (NU-B2139). Ventral valve moderately convex in lateral profile, most convex at about mid-length; umbo small; sulcus absent. Dorsal valve moderately concave in lateral profile, with deepest at mid-length; fold absent. External surface of both valves smooth; concentric growth lines not well preserved and obscure; hinge spines few in number near postero-lateral margins and diverging from hinge at about 60°. Ventral interior with short median septum, being one-fourth to one-fifth of valve length.

**Remarks.**—These specimens are safely assigned to the genus *Leiochonetes* by the small size, transversely semicircular outline and moderately concavo-convex shell, with smooth external surface and lacking both ventral sulcus and dorsal fold. The type species, *Leiochonetes salisburyensis* Roberts (1976, p. 27, pl. 3, figs. 1–9, text-figs. 6, 7), from the Flagstaff Sandstone (upper Visean) of Brownmore, New South Wales, eastern Australia, differs from *L. onimarensis* by the smaller size and more acute cardinal extremities. *Leiochonetes transversa* (Carter, 1967, p. 274, pl. 14, figs. 15–20), from the Chapel Limestone of central Texas, differs from the present new species by the much smaller and more transverse shell.

**Occurrence.**—HK2 Unit.

Suborder PRODUCTIDINA Waagen, 1883
Superfamily PRODUCTELLOIDEA Schuchert, 1929
Family PRODUCTINIDAE Muir-Wood and Cooper, 1960
Subfamily PRODUCTININAE Muir-Wood and Cooper, 1960
Genus *ARGENTIPRODUCTUS* Cooper and Muir-Wood, 1951

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

*Argentiproductus margaritaceus* (Phillips, 1836)
(Fig. 30B)

*Producta margaritacea* Phillips, 1836, p. 215, pl. 8, fig. 8.
*Productus margaritacea* Phillips. Davidson, 1861, p. 159, pl. 44, figs. 5–8.
*Productus* cf. *margaritaceus* Phillips. Yanishevsky, 1918, p. 45, pl. 8, fig. 38.
*Productus margaritaceus* Phillips. Delépine, 1928, p. 22, pl. 3, figs. 35, 36; Rotai, 1931, p. 55, pl. 3, fig. 4.
*Productus* (*Thomasina*) *margaritaceus* Phillips. Paeckelmann, 1931, p. 184, pl. 17, figs. 10–12.
*Thomasella margaritacea* (Phillips). Sarytcheva and Sokolskaya, 1952, p. 96, pl. 15, fig. 106.
*Argentiproductus margaritaceus* (Phillips). Muir-Wood and Cooper, 1960, pl. 123, figs. 11–16 only; Litvinovich et al., 1969, p. 155, pl. 7, figs. 18, 19; Volgin and Kushnar, 1975, p. 40, pl. 3, figs. 2–4; Bublichenko, 1976, p. 32, pl. 4, fig. 5; Brunton et al., 1993, p. 103, figs. 13–15; Sun and Baliński, 2008, p. 506, figs. 14–16.
*Productina margaritacea* (Phillips). Brunton, 1966, p. 209, pl. 8, figs. 1–19; pl. 15, figs. 1–8; Roberts, 1971, p. 94, pl. 17, figs. 11–28; Kalashnikov, 1974, p. 45, pl. 15, figs. 1–4; Galitskaya, 1977, p. 25, pl. 5, figs. 1–3; Donakova, 1978, p. 206, pl. 1, figs. 2, 3; Zakowa, 1985, p. 307, pl. 4, fig. 3; pl. 6, fig. 2.

**Material.**—One specimen from locality KAC1, external and internal moulds of a dorsal valve, NU-B2235.

**Remarks.**—The single dorsal valve specimen from Hikoroichi is medium in size (length 17 mm, width 28 mm), transversely hemispherical in outline, and strongly concave but not geniculate in lateral profile. External surface of the valve is ornamented by flattened costae (numbering 5–6 in 5 mm) on the trail, slightly irregular concentric lamellae on the visceral disc and numerous very fine concentric growth lines over the valve. Internal

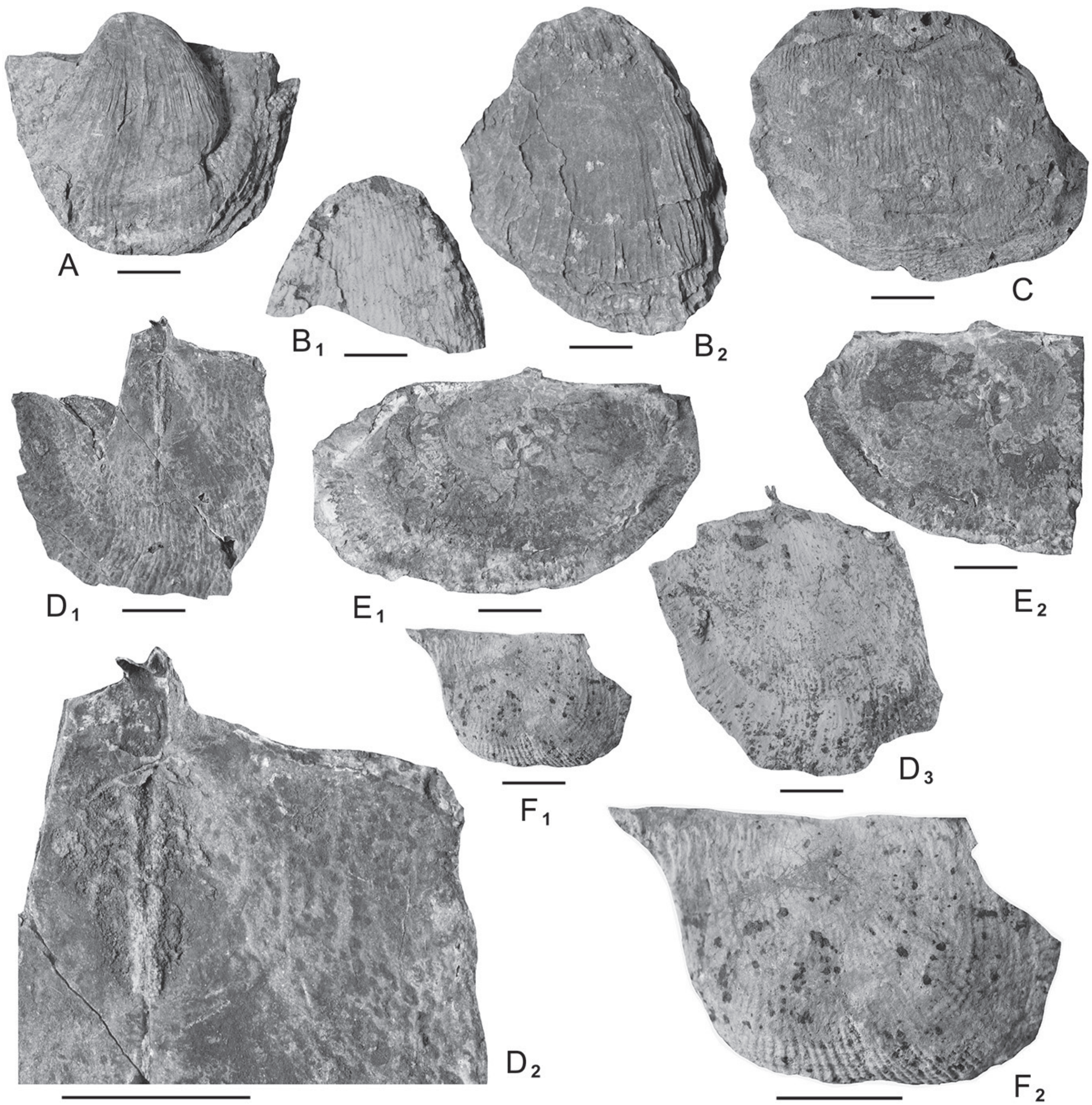


FIGURE 17. Brachiopods of the HK1 assemblage (2). **A–F,** *Tolmatchoffia robusta* (Tolmatchoff); A, internal mould of ventral valve, NU-B2178; B, external latex cast ($B_1$) and internal mould ($B_2$) of ventral valve, NU-B2174; C, internal mould of ventral valve, NU-B2177; D, internal mould ($D_1$, $D_2$) and external latex cast ($D_3$) of dorsal valve, NU-B2181; E, external mould ($E_1$) and internal mould ($E_2$) of dorsal valve, NU-B2180; F, external mould ($F_1$, $F_2$) of dorsal valve, NU-B2213. Scale bars represent 1 cm.

structures of the dorsal valve are obscure, except for a median septum which is extending to half length of the valve. This specimen is referred to *Argentiproductus margaritaceus* (Phillips, 1836), redescribed by Brunton et al. (1993, p. 103, figs. 13–15) from the upper Visean of Craven Reef Belt, Yorkshire, northern England, in size, shape and external ornament of the dorsal valve. *Argentiproductus pectinoides* (Phillips, 1836, p. 215, pl. 7, fig. 11), from the Visean of England, differs from *A. margaritaceus* in the smaller size and less transverse outline.

**Occurrence.**—HK4 Unit.

**Distribution.**—Upper Tournaisian–Serpukhovian: northeastern Japan (Hikoroichi in the South Kitakami Belt), northern Russia

(Pechora Basin), UK (England, Wales and northern Ireland), Poland, Germany, Belgium, western Russia (Moscow Basin and Donetz Basin), central Russia (southern Urals), Kazakhstan, Uzbekistan, Kyrgyzstan, southwestern China (Guizhou) and western Australia (Bonaparte Gulf Basin).

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)
(Figs. 17A–F, 22G–J)

*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.
*Buxtonia* sp. Tazawa, 1989, p. 60, pl. 1, figs. 6–9.

**Material.—**Twenty-one specimens from localities KF201 and KF202: (1) external and internal moulds of two ventral valves, NU-B2174, 2175; (2) external mould of a ventral valve, NU-B2176; (3) internal mould of four ventral valves, NU-B2043, 2177–2179; (4) external and internal moulds of seven dorsal valves, NU-B2044–2047, 2180–2182; (5) external moulds of five dorsal valves, NU-B2048–2051, 2183; and (6) internal moulds of two dorsal valves, NU-B2052, 2053.

**Description.—**Shell large in size for genus, slightly longer subrectangular in outline, widest at slightly anterior to midlength; length 58 mm, width 53 mm in the largest ventral valve specimen (NU-B2043); length 40 mm, width 66 mm in the largest dorsal valve specimen (NU-B2180). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region; umbo massive, strongly incurved; ears small; sulcus moderately deep; lateral slopes steep. Dorsal valve with large flattened visceral disc, strongly geniculated and followed by short trail. External surface of ventral valve ornamented with numerous costae, numbering 6–7 in 5 mm at about midlength; spines dense on ears. External ornament of dorsal valve weakly reticulate on visceral disc; spines absent. Ventral interior poorly preserved and obscure. Dorsal interior with large trilobate cardinal process, long, thin median septum and elongate dendritic adductor scars.

**Remarks.—**These specimens can be referred to *Tolmatchoffia 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 external features, particularly, the large size, short dorsal trail and dense spine bases on ears. *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 the smaller size and in having no ventral sulcus.

**Occurrence.—**HK1 and HK2 units.

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

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

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

*Marginatia burlingtonensis* (Hall, 1858)
(Fig. 23A–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; 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, 2017b, p. 335, figs. 6.3–6.5.
*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.—**Twenty-two specimens from localities KF171, KF172, KF174, KF188, KF201 and KF202: (1) external and internal moulds of a conjoined shell, NU-B629; (2) external and internal moulds of a ventral valve, NU-B631; (3) external mould of a ventral valve, NU-B632; (4) external and internal moulds of seven dorsal valves, NU-B633–639; and (5) external moulds of twelve dorsal valves, NU-B640–649, 2213, 2214.

**Remarks.—**These specimens can be referred to *Marginatia burlingtonensis* (Hall, 1858), redescribed by Weller (1914, p. 104, pl. 9, figs. 1–10) from the Burlington Limestone of the Mississippi Valley, on the basis of the medium size, transversely

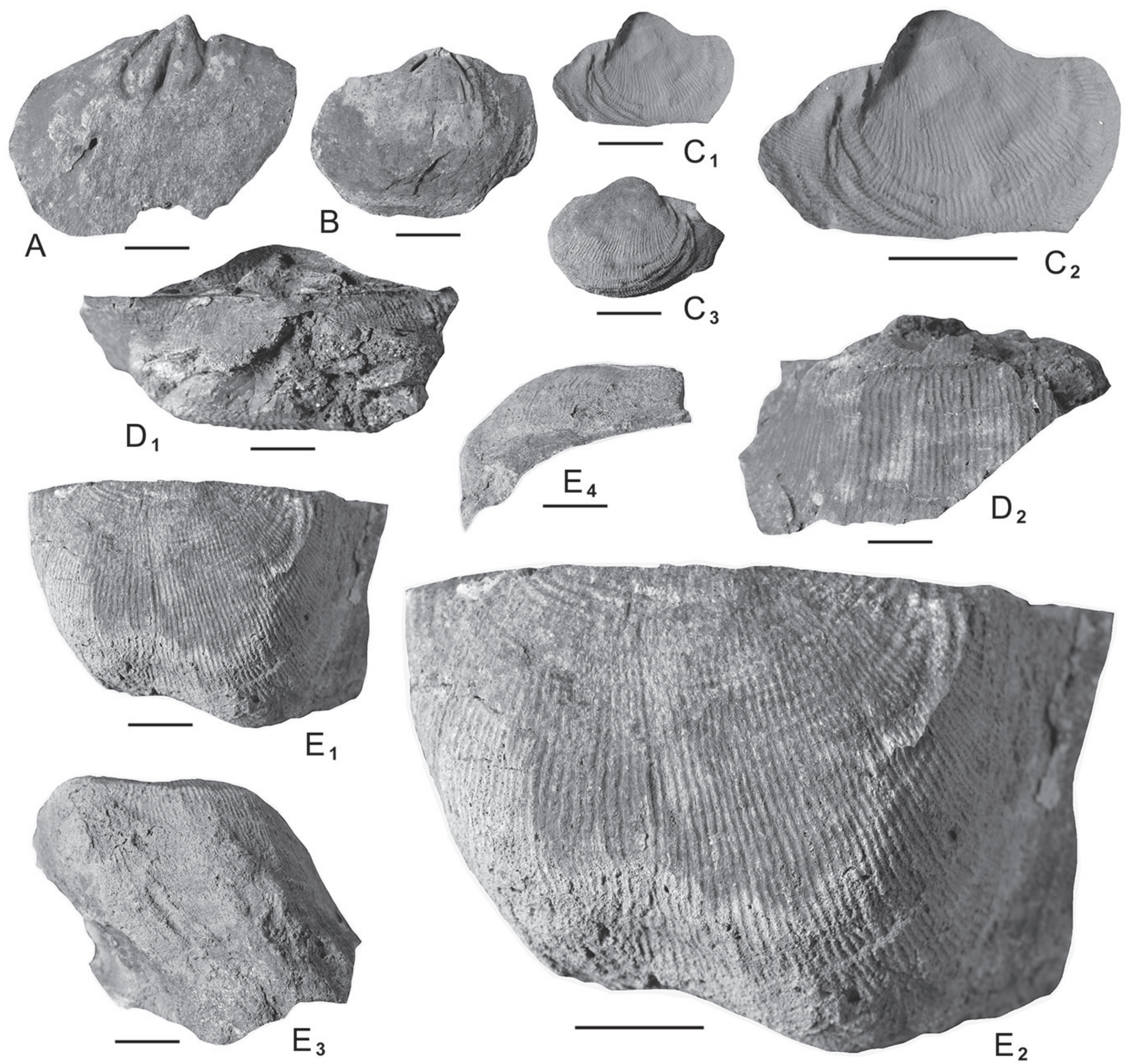


FIGURE 18. Brachiopods of the HK1 assemblage (3). **A, B,** ***Schizophoria resupinata*** (Martin); A, internal mould of ventral valve, NU-B2188; B, internal mould of dorsal valve, NU-B2190; **C,** ***Ovatia*** sp., external latex cast ($C_1$, $C_2$) and external mould ($C_3$) of dorsal valve, NU-B2202; **D, E,** ***Marginatia magna*** Carter; D, dorsal view ($D_1$) and anterior view ($D_2$) of external mould of dorsal valve, NU-B2185; E, dorsal ($E_1$, $E_2$), anterior ($E_3$) and lateral ($E_4$) views of external mould of dorsal valve, NU-B2184. Scale bars represent 1 cm.

rectangular outline and strongly geniculated dorsal valve, with regular and strong reticulate ornament on the visceral disc. *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.**—HK1 and HK2 units.

**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).

*Marginatia magna* Carter, 1968
(Fig. 18D, E)

*Marginatia magna* Carter, 1968, p. 1147, pl. 147, figs. 1–9; Garanj et al., 1975, p. 166, pl. 66, fig. 8; Carter, 1999, p. 102, fig. 3.

**Material.**—Four specimens from localities KF201 and KAC3: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, NU-B2184; and (2) external moulds of three dorsal valves, NU-B2185–2187.

**Remarks.**—The Hikorichi specimens are fragmentarily preserved, but they can be referred to *Marginatia magna* Carter (1968, p. 1147, pl. 147, figs. 1–9), from the Burlington Limestone of Missouri, in the large size (length more than 45 mm, width about 50 mm in the largest specimen, NU-B2184), moderately developed ventral sulcus and dorsal fold, strongly geniculated dorsal valve with long trail and slightly spreading lateral flanks, and external ornament of dorsal valve with reticulate on visceral disc and costate on trail and very fine numerous growth lines over the valve. The preceding species, *Marginatia burlingtonensis* (Hall, 1858), is readily distinguished from *M. magna* in the smaller size, much more finely ribbed dorsal valve, and in having a stronger fold–sulcus.

**Occurrence.**—HK1 Unit.

**Distribution.**—Upper Tournaisian: northeastern Japan (Hikoroichi in the South Kitakami Belt), USA (Missouri and Oklahoma) and central Russia (southern Urals).

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. 23G, 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; Litvinovich et al., 1969, p. 164, pl. 9, figs. 5, 6; pl. 10, fig. 1; Abramov, 1970, p. 117, pl. 9, fig. 4; Alexandrov 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) emend. 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; 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, 2017b, p. 335, figs. 6.6, 6.7.

*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.**—Three specimens from locality KF202: (1) internal moulds of two ventral valves, NU-B2061, 2062; and (2) external and internal moulds of a dorsal valve, NU-B2063.

**Description.**—Shell large in size for genus, transversely subcircular in outline, hinge slightly shorter than greatest width at midlength; length 38 mm, width about 50 mm in the better preserved ventral valve specimen (NU-B2061); length 31 mm, width 40 mm in the sole dorsal valve specimen (NU-B2063). Ventral valve moderately and unevenly convex in lateral profile, most convex at umbonal region; umbo rounded, massive and incurved; ears small, not clearly demarcated from visceral region; sulcus wide and shallow; lateral slopes gently convex and spreading. Dorsal valve weakly concave, nearly flat; no fold; trail not preserved. External surface of both valves ornamented with regular, strong concentric bands; numbering 4–5 bands in 10 mm on ventral valve; two rows of numerous elongate spine bases on each band of dorsal valve. Internal structures of both valves not well preserved.

**Remarks.**—These specimens can be referred to *Echinoconchus punctatus* (Sowerby, 1822), redescribed by Muir-Wood (1951, p. 102, pl. 4, fig. 2) and 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 England, in the large size and external ornament of both ventral and dorsal valves, consisting of regular strong concentric bands with rows of numerous elongate spine bases. *Echinoconchus defensus* (Thomas, 1914, p. 310, pl. 17, figs. 20–23), from the Visean of England and Scotland, differs from *E. punctatus* in the smaller size and in having more numerous concentric bands on the ventral valve. *Echinoconchus alternatus* (Norwood and Pratten, 1855), redescribed by Weller (1914, p. 138, pl. 17, figs. 1–7) from the Osagean of the Mississippi Valley, USA, resembles *E. punctatus* in size and outline, but the American species is distinguished from the latter by the presence of broader concentric bands on the ventral valve.

**Occurrence.**—HK2 Unit.

**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 *KARAVANKINA* Ramovs, 1969

**Type species.**—*Karavankina* typica Ramovs, 1969.

*Karavankina jizodoensis* Tazawa, 1980
(Fig. 30C, D)

*Karavankina jizodoensis* Tazawa, 1980, p. 362, pl. 41, figs. 8–16; pl. 42, fig. 14; text-fig. 2.
*Karavankina* sp. Tazawa, 1984b, p. 306, pl. 61, fig. 2.

**Material.**—Two specimens from locality KF167: (1) internal mould of a ventral valve, NU-B2233; and (2) external and internal moulds of a dorsal valve, IGPS97905.

**Description.**—Shell large in size for genus, transversely subrectangular in outline; length 18 mm, width more than 28 mm in the larger specimen (NU-B2233). Ventral valve gently convex in both lateral and anterior profiles; no sulcus. Dorsal valve gently concave, with nearly flat visceral disc; hinge straight, slightly narrower than greatest width at about three-quarters length of the valve; ears rather large, flat, trigonal and not clearly demarcated from visceral region; no fold. External surface of both valves ornamented with regular concentric lamellae, numbering 5–6 in 10 mm in ventral valve, and 7–9 in 10 mm in dorsal valve. Moreover, numerous somewhat quincunxially arranged elongate spine bases are preserved on the anterior portion of each lamella in the dorsal valve specimen (IGPS97905). Internally, ventral valve having a pair of narrow, elongate and smooth adductor scars in posterior portion of valve. Dorsal valve having a median septum and a pair of stout buttress plates.

**Remarks.**—These specimens are referred to *Karavankina jizodoensis* Tazawa (1980, p. 362, pl. 41, figs. 8–16; pl. 42, fig. 14; text-fig. 2), from the uppermost part of the Karaumedate Formation (upper Visean) of the Nagasaka area, South Kitakami Belt, on account of the large size (length 18 mm, width more than 28 mm), transversely subrectangular outline, external ornament of both valves consisting of numerous regular concentric lamellae, and the presence of a pair of stout buttress plates in the dorsal valve. *Karavankina dobsinensis* (Rakusz, 1932, p. 55, pl. 2, figs. 21, 22; pl. 3, fig. 2) from the Moscovian of Hungary, resembles the present species in size and shape of the ventral valve, but the Hungarian species differs from *K. jizodoensis* in having more numerous narrower concentric lamellae on the ventral valve.

**Occurrence.**—HK4 Unit.

**Distribution.**—Upper Visean: northeastern Japan (Hikoroichi and Nagasaka 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. 30F)

*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, 2017b, p. 336, figs. 7.3, 7.4.
*Productus* (*Pustula*) *pustulosus* Phillips emend. Thomas. Paeckelmann, 1931, p. 138, pl. 13, figs. 2, 3.
*Pustula* cf. *pustulosa* (Phillips). Mori and Tazawa, 1980, text-fig. 3.2; Tazawa, 1984b, p. 306, pl. 61, fig. 8.

**Material.**—One specimen from locality KF152, external mould of a dorsal valve, IGPS97904.

**Remarks.**—This specimen was figured by Mori and Tazawa (1980, text-fig. 3.2) and described by Tazawa (1984b, p. 306, pl. 61, fig. 8) as *Pustula* cf. *pustulosa* (Phillips, 1836). But the Hikoroichi species is identical with *Pustula pustulosa* (Phillips, 1836), redescribed by Thomas (1914, p. 261, pl. 17, figs. 24–28; pl. 18, fig. 1) from the upper Visean of Derbyshire, England, by the large size (length more than 35 mm, width about 76 mm), transversely subrectangular outline, well-developed dorsal fold and external ornament of dorsal valve consisting of regular concentric bands and numerous, quincunxially arranged elongate spine bases. *Pustula tenuipustulosa* Thomas (1914, p. 288, pl. 20, figs. 10, 11, text-fig. 7), from the lower Carboniferous of Wexford, Ireland, differs from *P. pustulosa* in having smaller spine bases and less-marked bands.

**Occurrence.**—HK4 Unit.

**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 laevicosta* (White, 1860)
(Fig. 23E, F)

*Productus laevicostus* White, 1860, p. 230.
*Ovatia laevicosa* (White). Sarytcheva et al., 1963, p. 226, pl. 37, figs. 3–5, text-fig. 100; Carter, 1999, p. 109, figs. 4I–N.

**Material.**—Two specimens from localities KF188 and KF202: (1) external and internal moulds of a ventral valve, NU-B2064; and (2) external mould of a ventral valve, NU-B2065.

**Remarks.**—These specimens are referred to *Ovatia laevicosta* (White, 1860), redescribed by Carter (1999, p. 109, figs. 4I–N) from the lower Osagean of Kenwood, northeastern Oklahoma, USA, in the relatively large size (length about 24 mm, width about 39 mm in the better preserved specimen, NU-B2064) and the number of costellae on the ventral valve (10–11 in 5 mm at about midlength). *Ovatia elongata* Muir-Wood and Cooper (1960, p. 312, pl. 114, figs. 1–4, 7, 11, 12), from the lower Fayetteville Formation of Fort Gibson, Oklahoma, differs from *O. laevicosta* in having a massive and strongly convex ventral umbo.

**Occurrence.**—HK2 Unit.

**Distribution.**—Upper Tournaisian–lower Visean: nortrheastern Japan (Hikoroichi in the South Kitakami Belt), USA (Iowa and Oklahoma) and central Russia (Kuznetsk Basin).

*Ovatia* cf. *prolata* Carter, 1987
(Fig. 30E)

cf. *Ovatia prolata* Carter, 1987, p. 40, pl. 5, figs. 1–17.

**Material.**—One specimen from locality KAC1, external mould of a ventral valve, NU-B2232.

**Remarks.**—This specimen is safely assigned to the genus *Ovatia* by the small (length 24 mm, width 22 mm), subovate and strongly convex ventral valve, ornamented with numerous fine costellae (numbering 16–18 in 5 mm at about midlength). The Hikoroichi species most resembles *Ovatia prolata* Carter (1987, p. 40, pl. 5, figs. 1–17), from the Banff Formation of western Alberta, in having fine costellae on the ventral valve. Accurate comparison is, however, difficult due to lack of the dorsal valve.

**Occurrence.**—HK4 Unit.

*Ovatia* sp.
(Fig. 18C)

**Material.**—One specimen from locality KF201, external mould of a dorsal valve, NU-B2202.

**Remarks.**—This specimen is safely assigned to the genus *Ovatia* by the small size (length about 20 mm, width about 25 mm), moderately concave dorsal valve, without fold, and the external ornament consisting of numerous regular costellae (numbering 12–13 in 5 mm at midlength) and strong concentric rugae on ears and the anterior part of the valve. The Hikoroichi species resembles *Ovatia ovata* (Hall, 1858), redescribed by Weller (1914, pl. 16, figs. 1–15) from the Chester Group of the Mississippi Valley, in size, shape and external ornament of the dorsal valve. But accurate comparison is difficult for the poorly preserved specimen.

**Occurrence.**—HK1 Unit.

Genus *LINOPROTONIA* Ferguson, 1971

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

*Linoprotonia ashfellensis* Ferguson, 1971
(Fig. 24A–C)

*Linoprotonia ashfellensis* Ferguson, 1971, p. 558, pl. 42, figs. 1–7, text-fig. 2A; Pattison, 1981, p. 11, pl. 1, figs. 1, 2; pl. 7, fig. 2; pl. 9, fig. 12; Tazawa and Ibaraki, 2009, p. 11, figs. 4.1–4.3.
*Gigantoproductus* sp. B Tazawa, 1984a, p. 58, pl. 1, figs. 4, 5 only.
*Linoprotonia* sp. Tazawa, 1989, p. 61, pl. 1, fig. 5 only.

**Material.**—Six specimens from locality KF202: (1) external and internal moulds of a ventral valve, NU-B597; and (2) internal moulds of five ventral valves, NU-B598–602.

**Remarks.**—These specimens were previously described by Tazawa and Ibaraki (2009, p. 11, figs. 4.1–4.3) as *Linoprotonia ashfellensis* Ferguson, 1971 on the basis of the linoproductid external features and gigantoproductid internal structures, particularly, in having small ears and flattened visceral disc in the ventral valve. Comparison with the other *Linoprotonia* species, *L. hemispaerica* (Sowerby, 1822) and *L. corrugatohemispherica* (Vaughan in Dixon and Vaughan, 1911), are fully discussed by Ferguson (1971, p. 559).

**Occurrence.**—HK2 Unit.

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

*Linoprotonia hikoroichiensis* Tazawa and Ibaraki, 2009
(Fig. 24D–H)

*Gigantoproductus* sp. B Tazawa, 1984a, p. 58, pl. 1, figs. 2, 3 only.
*Linoprotonia hikoroichiensis* Tazawa and Ibaraki, 2009, p. 11, figs. 5.1–5.5.

**Material.**—Eighteen specimens from locality KF202: (1) external and internal moulds of three ventral valves, NU-B603 (holotype), 604, 605; (2) external moulds of two ventral valves, NU-B606, 607; (3) internal moulds of seven ventral valves, NU-B608–614; (4) external and internal moulds of a dorsal valve, NU-B615; and (5) external moulds of five dorsal valves, NU-B616–620.

**Remarks.**—These specimens were described by Tazawa and

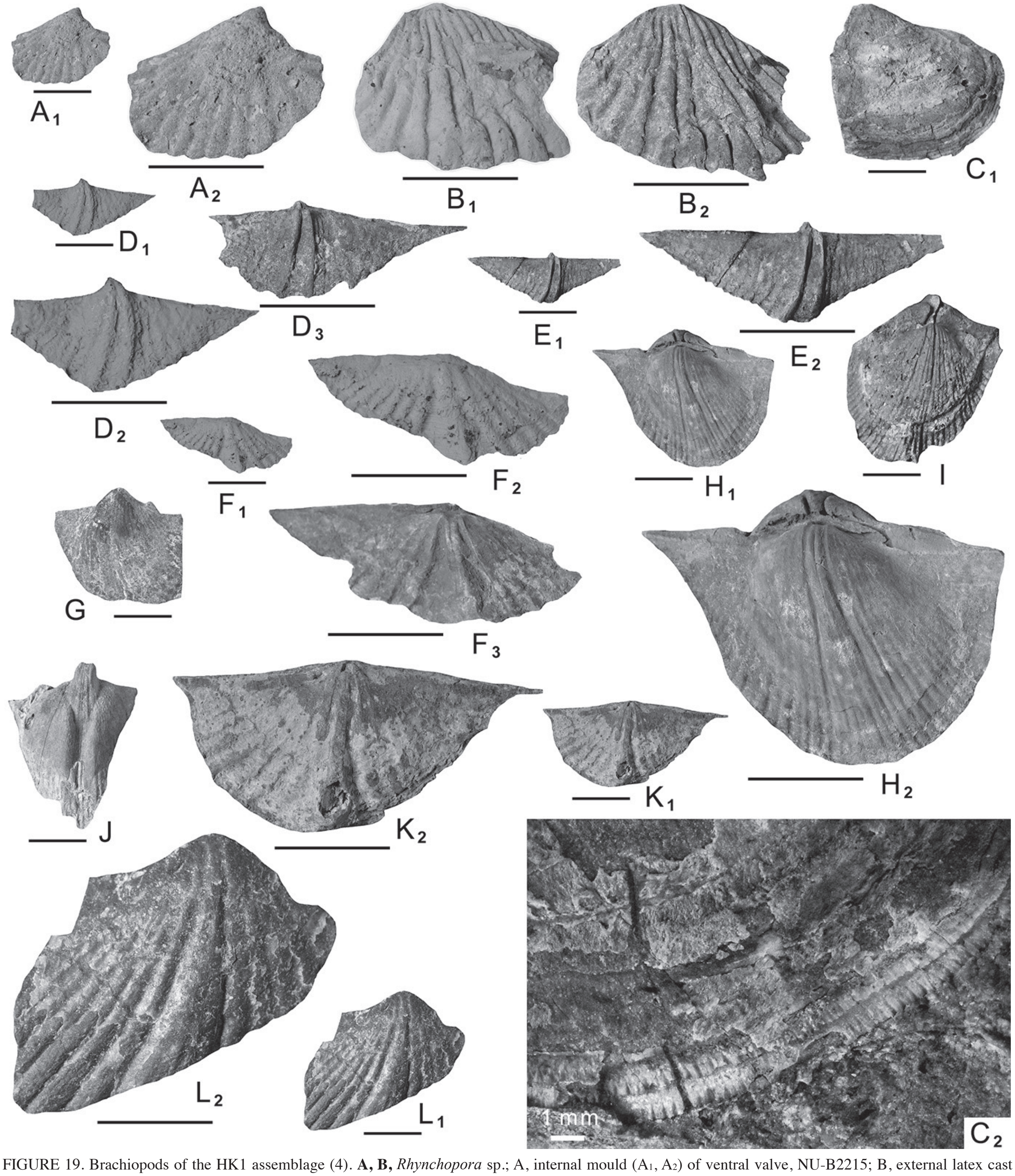


FIGURE 19. Brachiopods of the HK1 assemblage (4). **A, B,** *Rhynchopora* sp.; A, internal mould ($A_1$, $A_2$) of ventral valve, NU-B2215; B, external latex cast ($B_1$) and internal mould ($B_2$) of dorsal valve, NU-B2216; **C,** *Cleiothyridina harkeri* Carter, internal mould ($C_1$) and enlarged concentric lamellae ($C_2$) of ventral valve, NU-B2201; **D–F,** *Acuminothyris keokuk* Carter; D, external latex cast ($D_1$, $D_2$) and internal mould ($D_3$) of ventral valve, NU-B2118; E, internal mould ($E_1$, $E_2$) of ventral valve, NU-B2119; F, external latex cast ($F_1$, $F_2$) and internal mould ($F_3$) of dorsal valve, NU-B2120; **G–J,** *Unispirifer mediocris* (Tolmatchoff); G, internal mould of ventral valve, NU-B2209; H, internal mould ($H_1$, $H_2$) of dorsal valve, NU-B2212; I, internal mould of dorsal valve, NU-B2211; J, internal mould of ventral valve, NU-B2210; **K,** *Tylothyris laminosa* (M'Coy), internal mould ($K_1$, $K_2$) of dorsal valve, NU-B2205; **L,** *Brachythyris suborbicularis* (Hall), internal mould ($L_1$, $L_2$) of dorsal valve, NU-B2206. Scale bars represent 1 cm, unless otherwise specified.

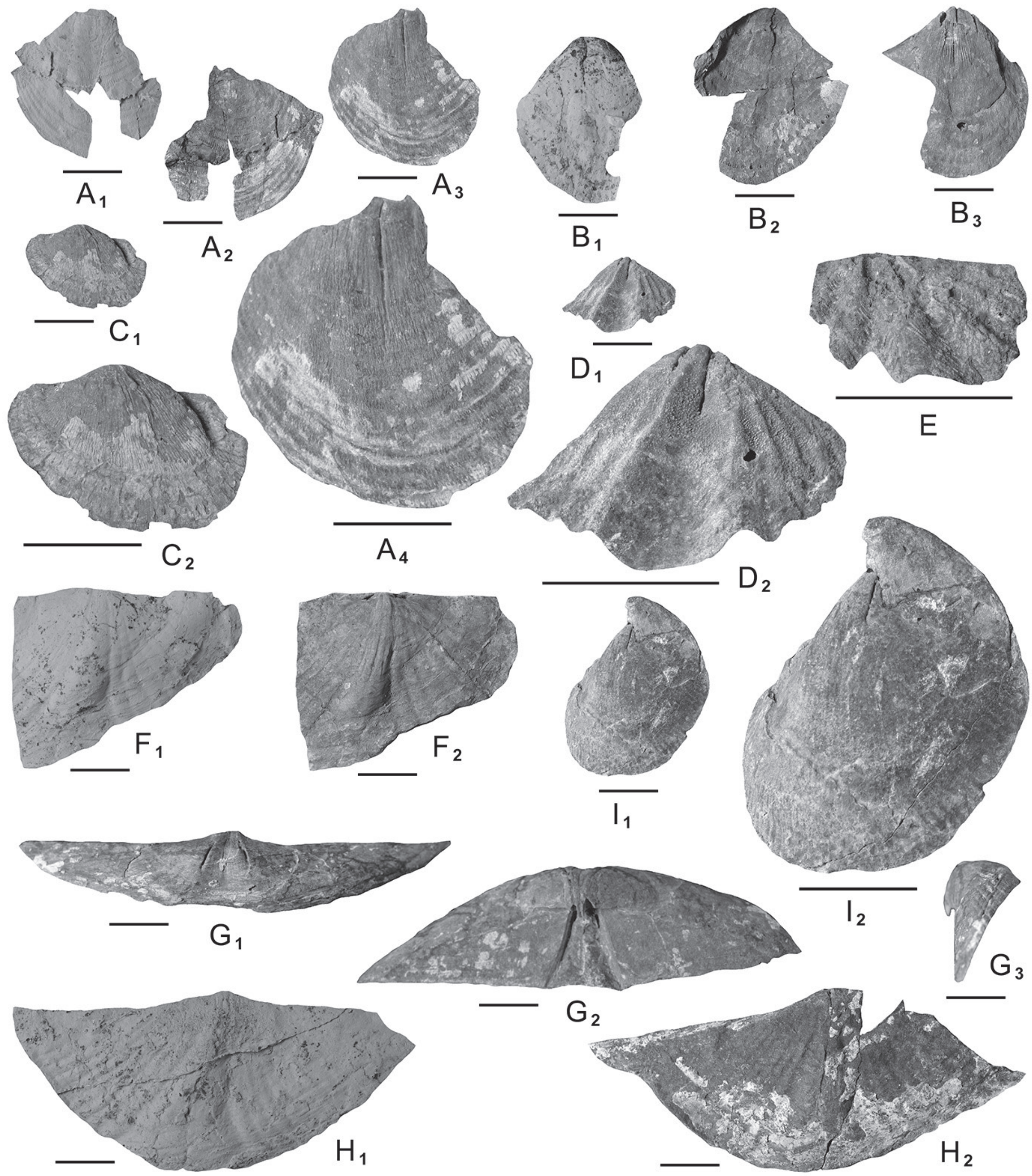


FIGURE 20. Brachiopods of the HK1 assemblage (5). **A,** *Kitakamithyris tyoanjiensis* Minato, external latex cast ($A_1$), external mould ($A_2$) and internal mould ($A_3$, $A_4$) of ventral valve, NU-B2191; **B, C,** *Kitakamithyris hikoroitiensis* Minato; B, external latex cast ($B_1$), external mould ($B_2$) and internal mould ($B_3$) of ventral valve, NU-B2193; C, internal mould ($C_1$, $C_2$) of dorsal valve, NU-B2196; **D, E,** *Punctospirifer* sp.; D, internal mould ($D_1$, $D_2$) of ventral valve, NU-B2207; E, internal mould of dorsal valve, NU-B2208; **F–H,** *Syringothyris sibirica* Sokolskaya; F, external latex cast ($F_1$) and internal mould ($F_2$) of dorsal valve, NU-B2200; G, ventral ($G_1$), posterior ($G_2$) and lateral ($G_3$) views of internal mould of ventral valve, N-B2197; H, external latex cast ($H_1$) and internal mould ($H_2$) of dorsal valve, NU-B2199; **I,** *Beecheria khalfini* Besnossova, ventral view of internal mould ($I_1$, $I_2$) of conjoined shell, NU-B2217. Scale bars represent 1 cm.

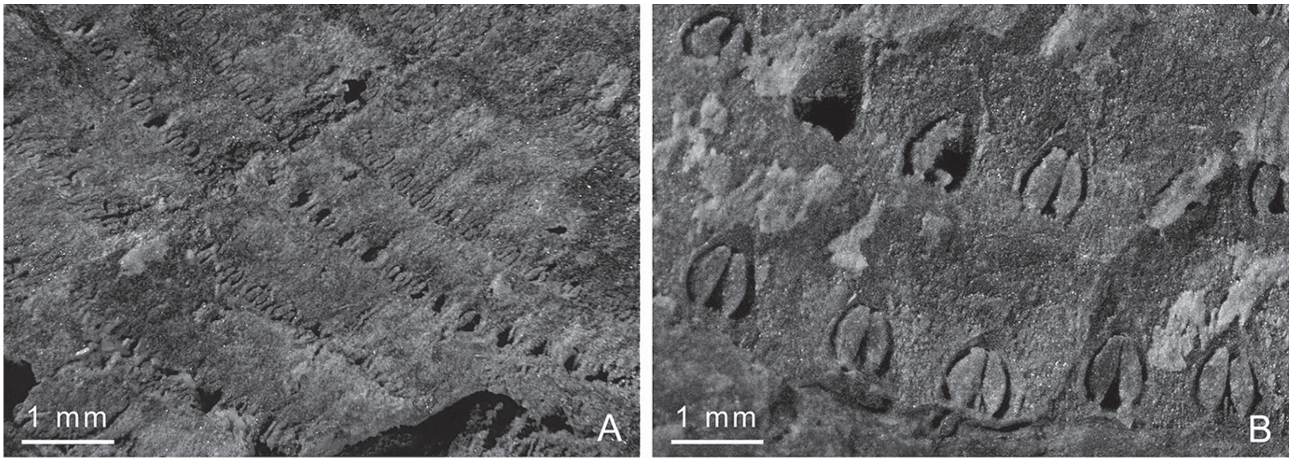


FIGURE 21. Brachiopods of the HK1 assemblage (6). Enlarged concentric rows of biramous spine bases; **A,** *Kitakamithyris tyoanjiensis* Minato, external mould of ventral valve, NU-B2191; **B,** *Kitakamithyris hikoroitiensis* Minato, external mould of ventral valve, NU-B2193.

Ibaraki (2009, p. 11, figs. 5.1–5.5) as *Linoprotonia hikoroichiensis* Tazawa and Ibaraki, 2009. This species is medium in size for genus, transversely semicircular to subquadrate in outline (length 36 mm, width 65 mm in the largest specimen, NU-B608), and having gently convex ventral valve, with large prominent ears and ornamented with fine costae (14–16 in 10 mm at mid-length). *L. hikoroichiensis* differs from the preceding species, *L. ashfellensis* Ferguson, 1971, by the less convex ventral valve, much larger prominent ears and finer costae on the ventral valve.

**Occurrence.**—HK2 Unit.

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

Subfamily GIGANTOPRODUCTINAE Muir-Wood and Cooper, 1960

Genus *GIGANTOPRODUCTUS* Prentice, 1950

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

*Gigantoproductus crassiventer* (Prentice, 1949)
(Fig. 25A, C)

*Gigantella crassiventer* Prentice, 1949, p. 257, pl. 11, fig. 1; pl. 12, fig. 1 only.
*Gigantoproductus* cf. *crassiventer* (Prentice). von Bitter and Legrand-Blain, 2007, p. 193, figs. 2B–F.
*Gigantoproductus* cf. *crassiventer* (Prentice). Tazawa and Ibaraki, 2009, p. 13, figs. 6.1, 6.2.

**Material.**—Three specimens from locality KF202: (1) external and internal moulds of a ventral valve, NU-B621; and (2) internal moulds of two ventral valves, NU-B622, 623.

**Remarks.**—These specimens were described by Tazawa and Ibaraki (2009, p. 13, figs. 6.1, 6.2) as *Gigantoproductus* cf. *crassiventer* (Prentice, 1949). However, the Hikoroichi specimens can be referred to *Gigantoproductus crassiventer* (Prentice, 1949), from the upper Visean of England, by the ventral valve of medium size and elongate outline (length about 62 mm, width about 56 mm in the best preserved specimen, NU-B622), with numerous costae (12–13 in 10 mm at midlength) over the valve and weak irregular ribbing on the anterior half of the valve. *Gigantoproductus elongatus* (Sarytcheva, 1928, p. 27, pl. 3, fig. 4), from the upper Visean of the Moscow Basin, differs from *G. crassiventer* by the more inflated ventral valve, having no sulcus and more strongly developed ribbing on the ventral valve.

**Occurrence.**—HK2 Unit

**Distribution.**—Lower–upper Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt), eastern Canada (Nova Scotia) and UK (England).

*Gigantoproductus latiexpansus* Sarytcheva in Sarytcheva and Sokolskaya, 1952
(Fig. 25B)

*Gigantoproductus latiexpansus* Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 130, pl. 33, fig. 176.
*Gigantoproductus* sp. A Tazawa, 1984a, pl. 1, fig. 1.
*Linoprotonia* sp. Tazawa, 1989, p. 61, pl. 1, fig. 4 only.
*Gigantoproductus* cf. *latiexpansus* Sarytcheva. Tazawa and Ibaraki, 2009, p. 15, fig. 7.1.

**Material.**—Three specimens from locality KF202: (1) external and internal moulds of a ventral valve, NU-B264; and (2) external moulds of two ventral valves, NU-B625, 626.

**Remarks.**—These specimens were described by Tazawa and Ibaraki (2009, p. 15, fig. 7.1) as *Gigantoproductus* cf. *latiexpansus* Sarytcheva in Sarytcheva and Sokolskaya, 1952. But the Hikoroichi specimens are referred to *Gigantoproductus latiexpansus* Sarytcheva (in Sarytcheva and Sokolskaya, 1952, p. 130, pl. 33, fig. 176), from the Venevian and Tarusian horizons of the Moscow Basin, in the transverse outline, ill-defined ears, irregular ribbing and fine costae (numbering 16–19 in 10 mm at about mid-length) on the ventral valve. *Gigantoproductus uniformis* Morozov (1988, p. 32, pl. figs. 1–5), from the upper Visean of the Moscow Basin, differs from *G. latiexpansus* in having coarser costae on the ventral valve.

**Occurrence.**—HK2 Unit.

**Distribution.**—Lower Visean–Serpukhovian: northeastern Japan (Hikoroichi in the South Kitakami Belt) and western Russia (Moscow Basin).

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. 25D, 30H)

*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 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.

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

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

**Material.**—Four specimens from localities KF167 and KF202: (1) external cast of a ventral valve, NU-B2103; (2) external and internal moulds of a ventral valve, NU-B2104; (3) external mould of a ventral valve, NU-B2105; and (4) external and internal moulds of a dorsal valve, IGPS97903.

**Description.**—Shell large in size for genus, transversely semicircular in outline, hinge slightly shorter than greatest width at about midlength; length about 45 mm, width about 78 mm in the largest specimen (NU-B2104); length 57 mm, width about 62 mm in a relatively well preserved ventral valve specimen (NU-B2105). Ventral valve nearly flat to slightly concave in lateral profile, no sulcus. External surface of ventral valve ornamented with numerous costellae, irregular strong rugae and numerous very fine growth lines; costellae subangular and having much wider intercostal spaces (parvicostellate), often intercalated, numbering 7–9 in 5 mm near anterior margin of ventral valve. Ventral interior with a strong median septum extending to one third length of valve and faintly preserved large flabellate muscle scars.

**Remarks.**—These specimens 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 size, shape and external ornament of the ventral valve, particularly, being widest at about midlength. The most allied species, *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 the present species by the smaller size and less transverse outline.

**Occurrence.**—HK2 and HK4 units.

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

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. 26A–C, 30G)

*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 et al., 1969, p. 127, pl. 1, figs. 9, 10; Bublichenko, 1971, p. 29, pl. 2, figs. 9–12; Alexandrov 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.

*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.

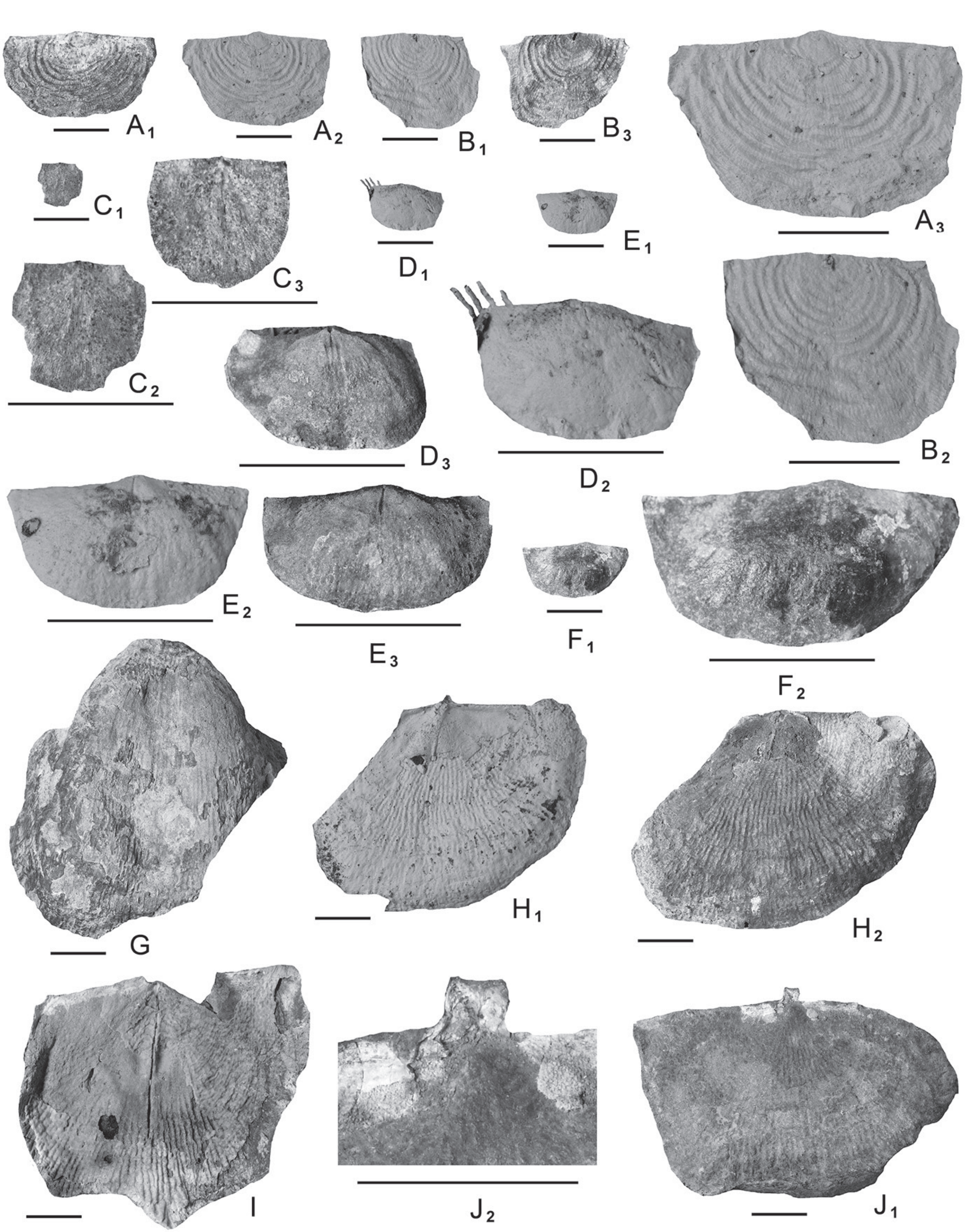


FIGURE 22. Brachiopods of the HK2 assemblage (1). **A, B,** *Leptagonia analoga* (Phillips); A, external mould ($A_1$) and external latex cast ($A_2$, $A_3$) of ventral vlave, NU-B2081; B, external latex cast ($B_1$, $B_2$) and external mould ($B_3$) of dorsal valve, NU-B2083; **C,** *Rugosochonetes* cf. *hardrensis* (Phillips), external mould ($C_1$, $C_2$) and internal mould ($C_3$) of dorsal valve, NU-B2042; **D–F,** *Leiochonetes onimarensis* sp. nov.; D, external latex cast ($D_1$, $D_2$) and internal mould ($D_3$) of ventral valve, NU-B2136 (holotype); E, external latex cast ($E_1$, $E_2$) and internal mould ($E_3$) of ventral valve, NU-B2137; F, external mould ($F_1$, $F_2$) of dorsal valve, NU-B2139; **G–J,** *Tolmatchoffia robusta* (Tolmatchoff); G, internal mould of ventral valve, NU-B2043; H, internal latex cast ($H_1$) and external mould ($H_2$) of dorsal valve, NU-B2047; I, internal mould of dorsal valve, NU-B2045; J, external mould ($J_1$) and cardinal process ($J_2$) of dorsal valve, NU-B2048. Scale bars represent 1 cm.

**Material.**—Eight specimens from localities KF163 and KF202: (1) external and internal moulds of a ventral valve, NU-B2054; (2) internal moulds of two ventral valves, NU-B2055, 2056; (3) interior of a ventral valve, IGPS97900; (4) two abraded dorsal valves, IGPS97899, 97901; and (5) internal mould of two dorsal valves, NU-B2057, IGPS97902.

**Description.**—Shell medium in size for genus, subcircular in outline, gently dorsibiconvex, with short hinge and maximum width at slightly anterior to midlength; length 16 mm, width 18 mm in the best preserved ventral valve specimen (NU-B2054). Ventral valve gently convex; sulcus absent. External surface of ventral valve ornamented with numerous costellae, numbering 6–7 in 2 mm near anterior margin. Ventral interior with large flabellate muscle scars bisected in front of adductor scars by short median ridge. Dorsal interior with strong brachiophores and large quadripartite muscle scars.

**Remarks.**—These specimens are 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 size and outline of the ventral valve, particularly, in having short hinge and the widest part at slightly anterior to midlength. *Rhipidomella* sp., described by Tazawa and Katayama (1979, p. 170, pl. 11, figs. 1–7) and Tazawa (1984b, p. 305, pl. 61, figs. 5–7) from the Odaira and Hikoroichi Formations of the South Kitakami Belt, are conspecific with 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 longer hinge and the widest part at midlength of the shell.

**Occurrence.**—HK2 and HK4 units.

**Distribution.**—Upper Tournaisian–lower Bashkirian: northeastern Japan (Hikoroichi and Yokota 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).

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. 18A, B, 26G, H, 31A–E)

*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; Ustritskiy 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; 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 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.

*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.

**Material.**—Sixteen specimens from localities KAC1, KF167, KF188, KF200 and KF201: (1) external and internal moulds of five ventral valves, NU-B2188, 2189, 2218–2220; (2) internal mould of five ventral valves, IGPS97898, NU-B2058, 2221–2223; (3) external and internal moulds of a dorsal valve, NU-B2224; and (4) internal moulds of five dorsal valves, NU-B2059, 2060, 2190, 2225, 2226.

**Remarks.**—These specimens 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 UK (England, Wales and Isle of Man), in the medium size (length about 42 mm, width about 55 mm in the largest specimen, NU-B2218), wider subrectangular outline,

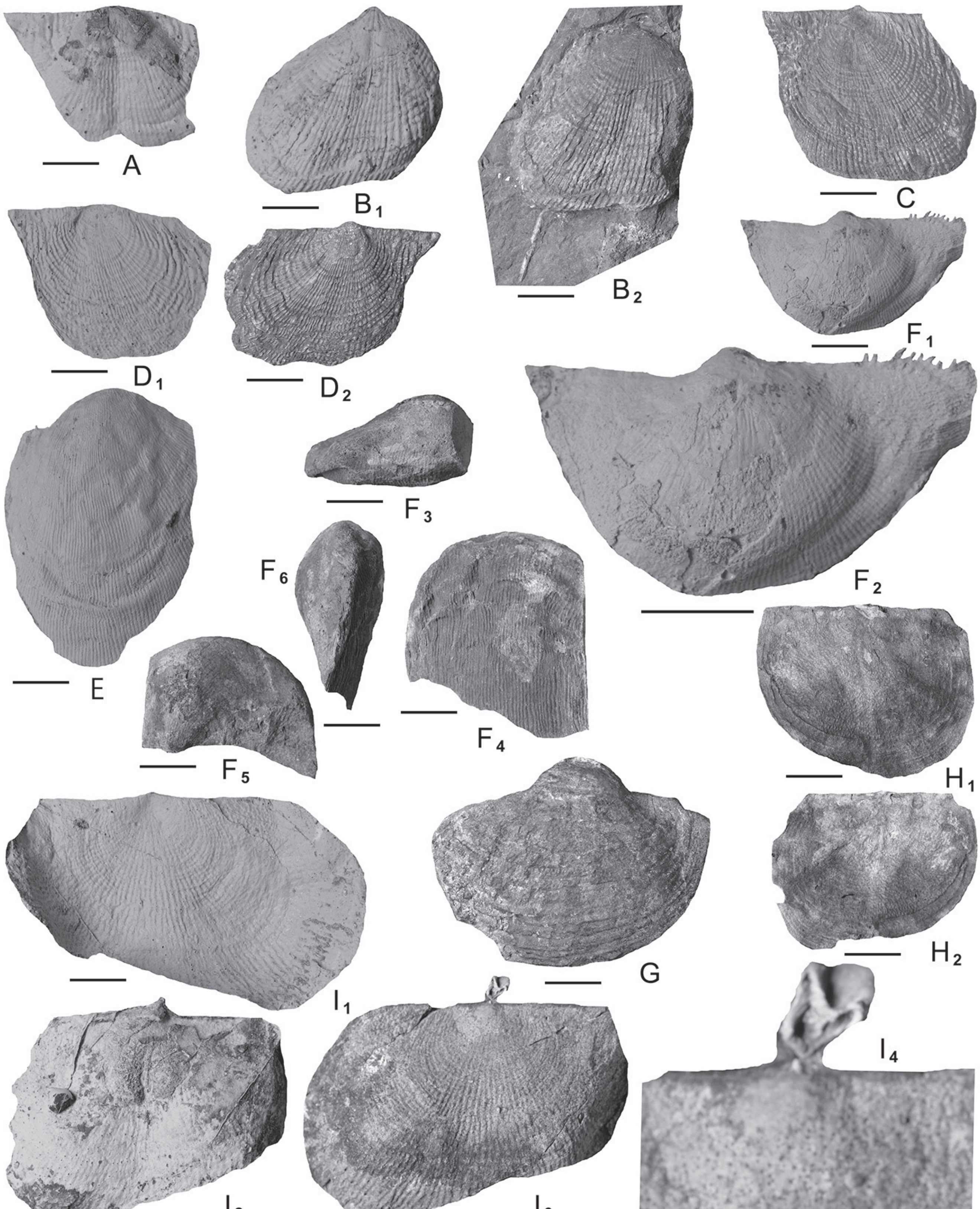


FIGURE 23. Brachiopods of the HK2 assemblage (2). **A–D**, *Marginatia burlingtonensis* (Hall); A, external latex cast of dorsal valve, NU-B629; B, internal latex cast ($B_1$) and internal mould ($B_2$) of dorsal valve, NU-B633; C, external mould of dorsal valve, NU-B634; D, external latex cast ($D_1$) and external mould ($D_2$) of dorsal valve, NU-B643; **E, F,** *Ovatia laevicosta* (White); E, external latex cast of ventral valve, NU-B2065; F, external latex cast ($F_1$, $F_2$) and ventral view ($F_3$), anterior view ($F_4$), posterior view ($F_5$) and lateral view ($F_6$) of external mould of ventral valve, NU-B2064; **G, H,** *Echinoconchus punctatus* (Sowerby); G, internal mould of ventral valve, NU-B2061; H, external mould ($H_1$) and internal mould ($H_2$) of dorsal valve, NU-B2063; **I,** *Tolmatchoffia robusta* (Tolmatchoff), external latex cast ($I_1$), internal latex cast ($I_2$), external mould ($I_3$) and cardinal process ($I_4$) of dorsal valve, NU-B2044. Scale bars represent 1 cm.

moderately convex dorsal valve and the ventral muscle field moderately incised, flabellate. *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 UK (Scotland, England, Wales and Isle of Man), differs from the present species in the smaller size and in having more strongly incised, elliptical muscle field in the ventral valve.

**Occurrence.—**HK1, HK2 and HK4 units.

**Distribution.—**Upper Tournaisian–upper Visean: northeastern Japan (Hikoroichi and Yokota 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, Wales, and Isle of Man), Poland, Belgium, Spain, western Russia (Moscow Basin and Donetz Basin), 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).

Order RHYNCHONELLIDA Kuhn, 1949
Superfamily RHYNCHOPOROIDEA Muir-Wood, 1955
Family RHYNCHOPORIDAE Muir-Wood, 1955
SubfamilyRHYNCHOPORINAE Muir-Wood, 1955
Genus *RHYNCHOPORA* King, 1865

**Type species.—***Terebratula genitziana* de Verneuil, 1845.

*Rhynchopora* sp.
(Fig. 19A, B)

**Material.—**Two specimens from locality KF201: (1) internal mould of a ventral valve, NU-B2215; and (2) external and internal moulds of a dorsal valve, NU-B2216.

**Description.—**Shell large in size for genus, transversely subpentagonal in outline, with greatest width at about midlength; length 16 mm, width about 22 mm in the larger specimen (NU-B2216); length 15 mm, width 18 mm in the smaller specimen (NU-B2215). Ventral valve gently convex in both lateral and anterior profiles; umbo small, pointed; sulcus wide and shallow; external ornament consisting of numerous simple rounded costae, numbering seven on sulcus and five on each lateral slope. Internal structure of ventral valve not well preserved. Dorsal valve much more convex than ventral valve; fold wide and low; external ornament consisting of 17 or more simple, broad and rounded costae. Interior of dorsal valve with a short and thin median septum.

**Remarks.—**These specimens are safely assigned to the genus *Rhynchopora* by the transversely subpentagonal outline. The Hikoroichi species most resembles *Rhynchopora sansabensis* Carter (1967, p. 314, pl. 26, figs. 1–8, text-figs. 8, 9), from the Chappel Limestone of Texas, in size, shape and external ornament of both valves, although the number of costae are slightly fewer than the Texan species. *Rhynchopora persinuata* (Winchell, 1865), redescribed by Carter (1999, p. 115, figs. 8E–bb, 9), from the lower Osagean of Oklahoma, differs from the present species in the smaller size and in having more numerous fine costae on the ventral sulcus.

**Occurrence.—**HK1 Unit.

Superfamily RHYNCHOTETRADOIDEA Licharew in Rzhonsnitskaya, 1956
Family TETRACAMERIDAE Licharew in Rzhonsnitskaya, 1956
Genus *ROTAIA* Rzhonsnitskaya, 1959

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

*Rotaia hikoroichiensis* Tazawa, 2006
(Figs. 26E, F, 30I)

*Rotaia* sp. Tazawa, 1996, p. 8, fig. 4; Tazawa, 2002, figs. 7.3–7.5.
*Rotaia hikoroichiensis* Tazawa, 2006, p. 135, figs. 8.1–8.3.

**Material.—**Three specimens from localities KF156 and KF202, external and internal moulds of three ventral valves, NU-B49, 2173, 2227.

**Remarks.—**Of the two specimens, the larger one (NU-B49) was described by Tazawa (2006, p. 135, figs. 8.1–8.3) as *Rotaia hikoroichiensis* Tazawa, 2006. The smaller one also is referred to *R. hikoroichiensis* by the large ventral valve with ill-defined sulcus and coarse costae. Comparison with the other species of *Rotaia* has been discussed by Tazawa (2006, p. 136).

**Occurrence.—**HK2 and HK4 units.

**Distribution.—**Lower–upper Visean: northeastern Japan (Hikoroichi 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 ATHYRIDINAE Davidson, 1881
Genus *ACTINOCONCHUS* M'Coy, 1844

**Type species.—***Actinoconchus paradoxus* M'Coy, 1844.

*Actinoconchus expansus* (Phillips, 1836)
(Fig. 26I, J)

*Spirifera expansa* Phillips, 1836, p. 220, pl. 10, fig. 8.
*Athyris expansa* (Phillips). Davidson, 1859, p. 82, pl. 16, figs. 14, 16; pl. 17, fig. 3 only.
*Athyris* (*Actinoconchus*) expansa (Phillips). Licharew, 1934, p. 45, 115, pl. 8, figs. 4, 5.
*Actinoconchus expansus* (Phillips). Nalivkin and Fotieva, 1973, p. 75, pl. 24, fig. 7.
*Actinoconchus*? *expansus* (Phillips). Poletaev, 1975, p. 89, pl. 21, figs. 1–6, text-fig. 19.
*Cleiothyridina expansa* (Phillips). Jin et al., 1979, p. 124, pl. 36, figs. 35, 36.
*Actinoconchus expansus expansus* (Phillips). Brunton, 1980, p.

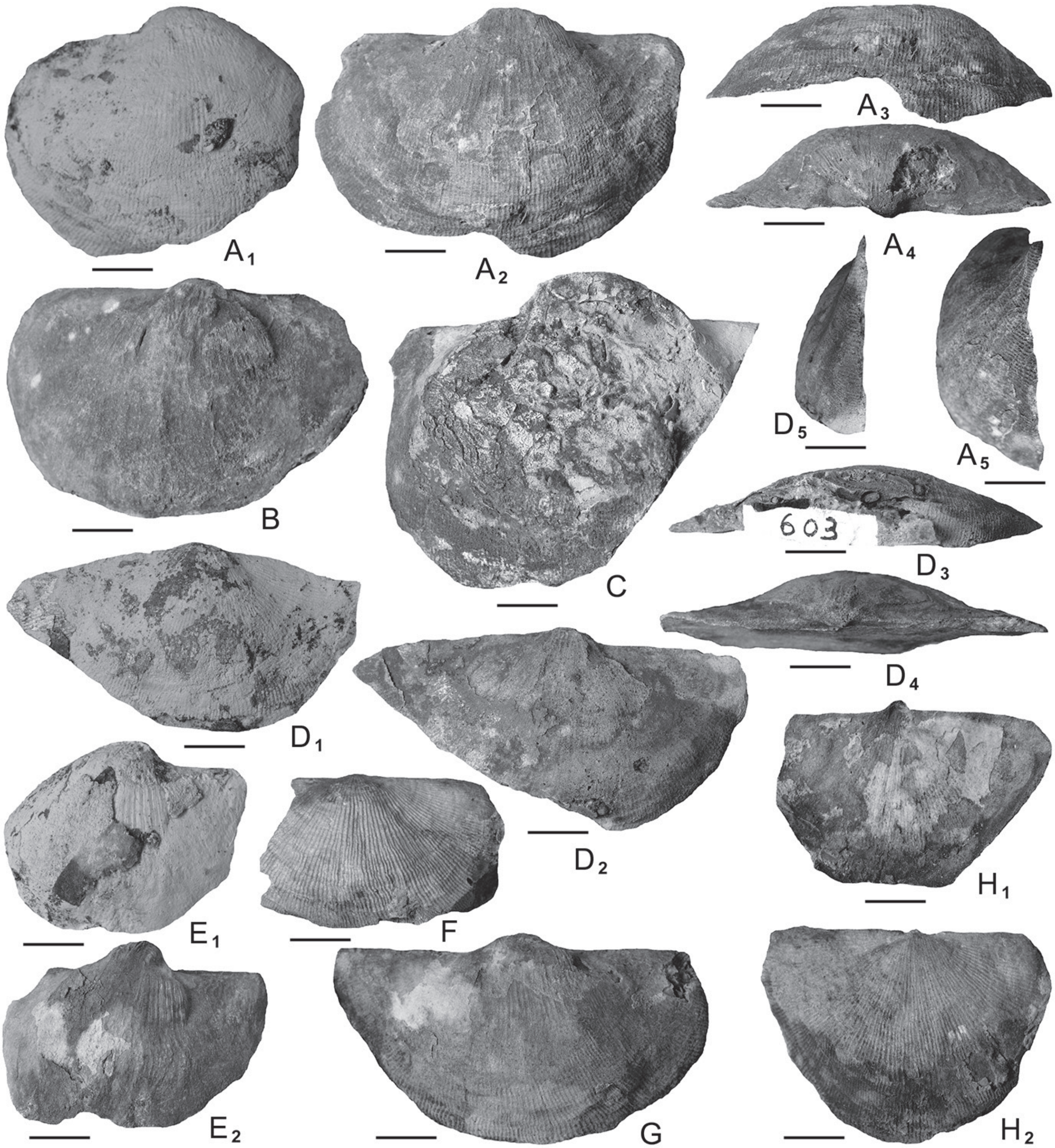


FIGURE 24. Brachiopods of the HK2 assemblage (3). **A–C,** *Linoprotonia ashfellensis* Ferguson; A, external latex cast ($A_1$), ventral ($A_2$), anterior ($A_3$), posterior ($A_4$) and lateral ($A_5$) views of internal moud of ventral valve, NU-B597; **D–H,** *Linoprotonia hikoroichiensis* Tazawa and Ibaraki; D, external latex cast ($D_1$), ventral ($D_2$), anterior ($D_3$), posterior ($D_4$) and lateral ($D_5$) views of ventral valve, NU-B603; E, external latex cast ($E_1$) and internal mould ($E_2$) of ventral valve, NU-B604; F, external mould of dorsal valve, NU-B616; G, internal mould of ventral valve, NU-B608; H, internal mould ($H_1$) and external mould ($H_2$) of dorsal valve, NU-B615. Scale bars represent 1 cm.

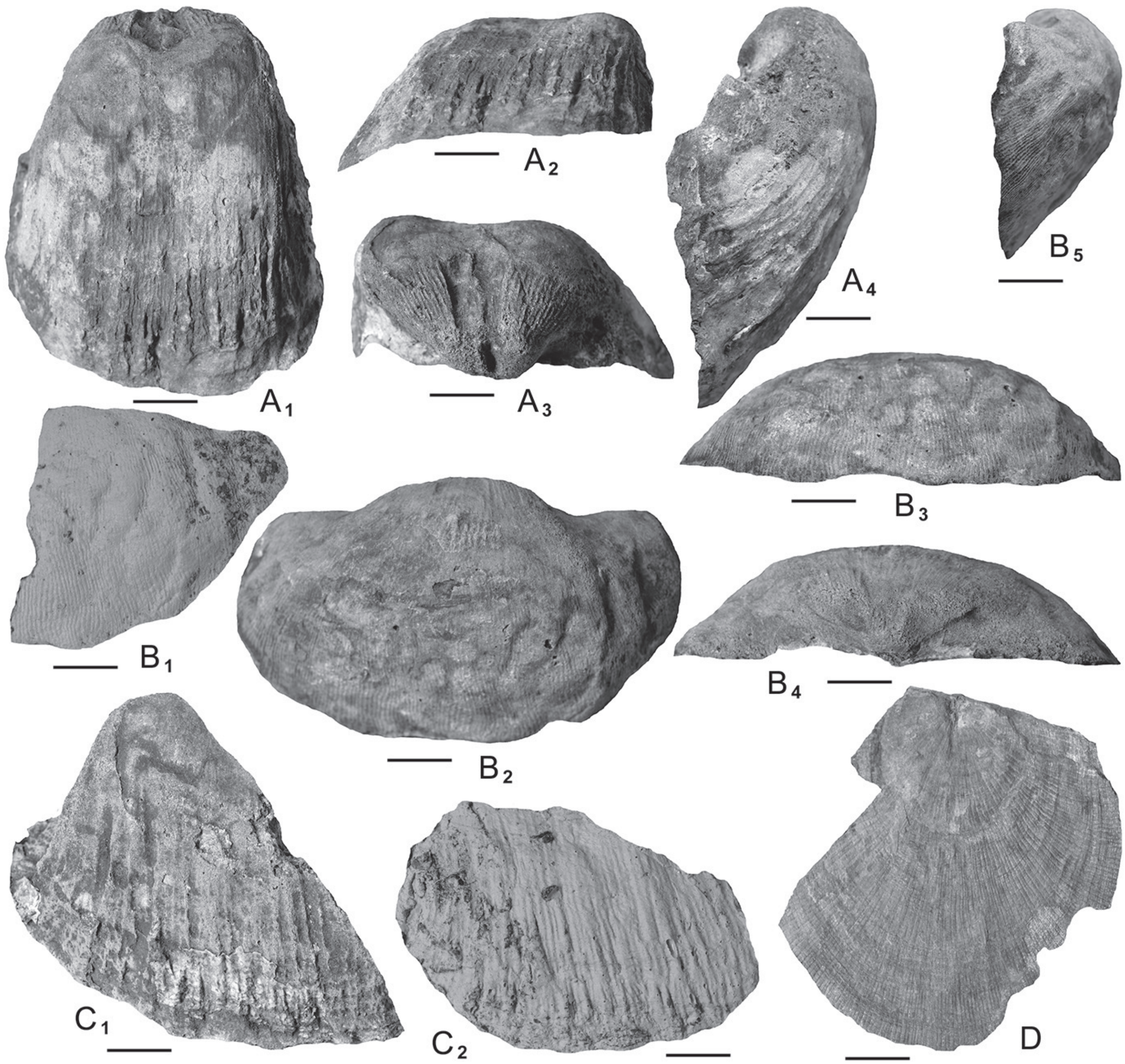


FIGURE 25. Brachiopods of the HK2 assemblage (4). **A, C,** *Gigantoproductus crassiventer* (Prentice); A, ventral ($A_1$), anterior ($A_2$), posterior ($A_3$) and lateral ($A_4$) views of internal mould of ventral valve, NU-B622; C, internal mould ($C_1$) and external latex cast ($C_2$) of ventral valve, NU-B621; **B,** *Gigantoproductus latiexpansus* Sarytcheva, external latex cast ($B_1$), and ventral ($B_2$), anterior ($B_3$), posterior ($B_4$) and lateral ($B_5$) views of internal mould of ventral valve, NU-B624; **D,** *Orthotetes keokuk* (Hall), external mould of ventral valve, NU-B2105. Scale bars represent 1 cm.

222, fig. 10.

**Material.**—Three specimens from locality KF202: (1) external and internal moulds of a ventral valve, NU-B2110; and (2) external and internal moulds of two dorsal valves, NU-B2111, 2112.

**Description.**—Shell large in size for genus, transversely oval to elliptical in outline, with greatest width at about midlength; length about 25 mm, width about 29 mm in the single ventral valve specimen (NU-B2110); length about 23 mm, width about 32 mm in the larger dorsal valve specimen (NU-B2111). Ventral valve gently convex in both lateral and anterior profiles; umbo small; sulcus absent. Dorsal valve slightly convex in both profiles; fold absent. External surface of both valves ornamented with numerous concentric lamellae with short flanges, numbering 5–6 lamellae in 3 mm near anterior margin of ventral valve. Internal surface of ventral valve sculptured with faint radial vascular markings. Dorsal interior with a pair of stout diverging socket

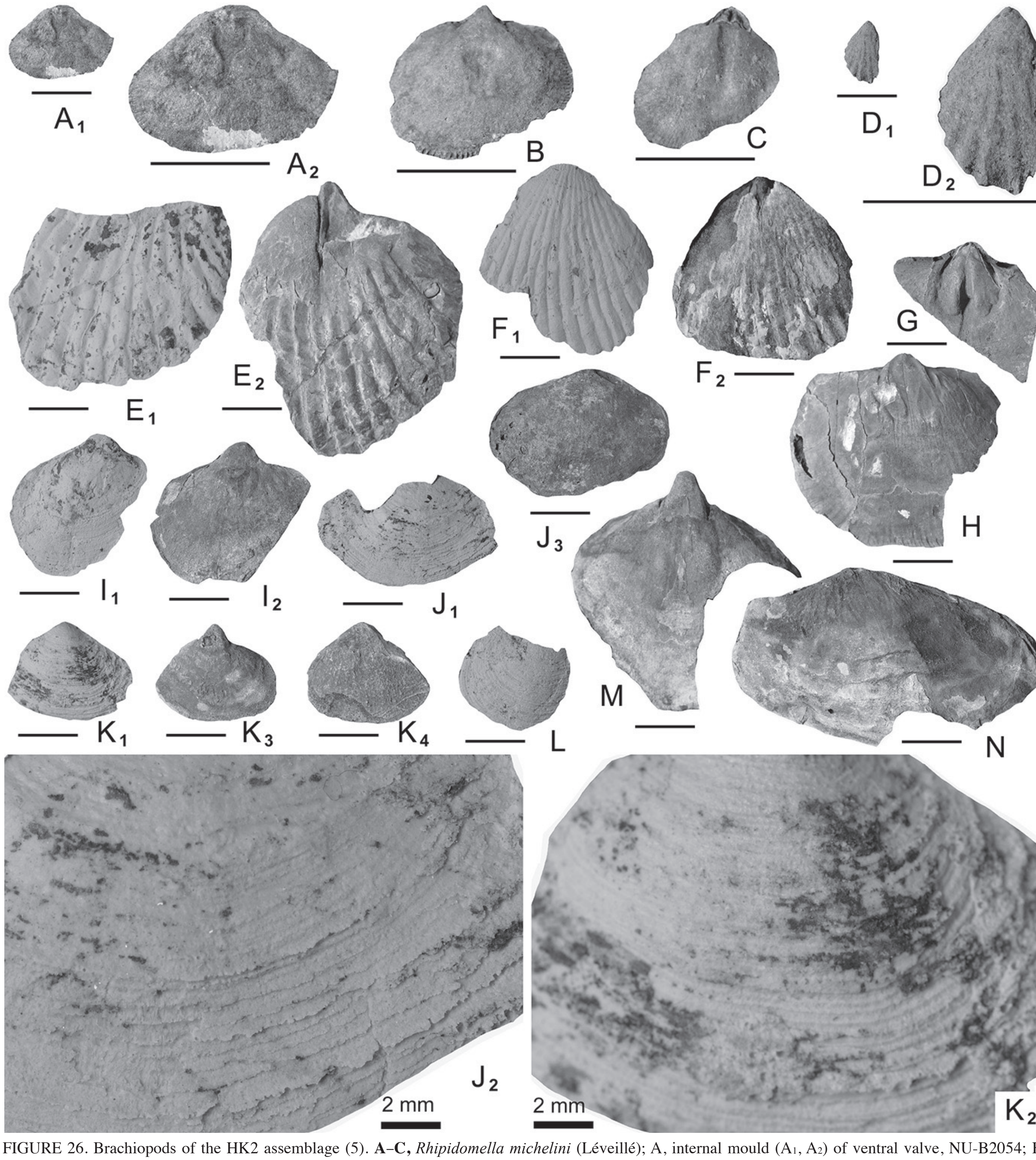


FIGURE 26. Brachiopods of the HK2 assemblage (5). **A–C,** *Rhipidomella michelini* (Léveillé); A, internal mould ($A_1$, $A_2$) of ventral valve, NU-B2054; B, internal mould of ventral valve, NU-B2056; C, internal mould of dorsal valve, NU-B2057; **D,** *Hustedia* sp., internal mould ($D_1$, $D_2$) of ventral valve, NU-B2109; **E, F,** *Rotaia hikoroichiensis* Tazawa; E, external latex cast ($E_1$) and internal mould ($E_2$) of ventral valve, NU-B49; F, external latex cast ($F_1$) and internal mould ($F_2$) of ventral valve, NU-B2173; **G, H,** *Schizophoria resupinata* (Martin); G, internal mould of ventral valve, NU-B2058; H, internal mould of dorsal valve, NU-B2059; **I, J,** *Actinoconchus expansus* (Phillips), I, external latex cast ($I_1$) and internal mould ($I_2$) of ventral valve, NU-B2110; J, external latex cast ($J_1$), enlarged concentric lamellae ($J_2$) and internal mould ($J_3$) of dorsal valve, NU-B2111; **K, L,** *Actinoconchus paradoxus* M'Coy; K, external latex cast ($K_1$), enlarged concentric lamellae ($K_2$) and internal mould ($K_4$) of dorsal valve, and internal mould ($K_3$) of ventral valve, NU-B2113; L, external latex cast of ventral valve, NU-B2114; **M, N,** *Lamellosathyris qaidamensis* Chen, Shi and Zhan; M, internal mould of ventral valve, NU-B2036; N, internal mould of dorsal valve, NU-B2039. Scale bars represent 1 cm, unless otherwise specified.

ridges.

**Remarks.**—These specimens are referred to *Actinoconchus expansus* (Phillips, 1836), redescribed by Brunton (1980, p. 222, fig. 10) as *Actinoconchus expansus expansus* (Phillips, 1836) from the lower Visean of Bolland, Yorkshire, in the large size and transversely elliptical outline. *Actinoconchus patulus* Brunton (1980, p. 222, figs. 7–9), from the Visean of England, is readily distinguished from *A. expansus* by the lower and wider outline.

**Occurrence.**—HK2 Unit.

**Distribution.**—Lower Visean–Serpukhovian: northeastern Japan (Hikoroichi in the South Kitakami Belt), northern Russia (Kolyma), UK (England), western Russia (Donetz Basin), central Russia (western Urals) and northwestern China (Qinghai).

*Actinoconchus paradoxus* M'Coy, 1844
(Fig. 26K, L)

*Actinoconchus paradoxus* M'Coy, 1844, p. 150, pl. 21, fig. 6; Brunton, 1980, p. 221, figs. 4–6.
*Athyris planosulcata* (Phillips). Davidson, 1859, p. 80, pl. 16, figs. 9–11 only.

**Material.**—Two specimens from locality KF202: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, NU-B2113; and (2) external mould of a ventral valve, NU-B2114.

**Remarks.**—These specimens can be referred to *Actinoconchus paradoxus* M'Coy, 1844, redescribed by Brunton (1980, p. 221, figs. 4–6) on the type specimens from the lower Visean of County Kildare, Ireland, by the small (length 18 mm, width about 23 mm in the better preserved specimen, NU-B2113), subcircular and moderately convex ventral valve without sulcus and the external ornament consisting of numerous concentric lamellae (numbering 5–6 in 3 mm near anterior valve margin) with faint radiating striations. *Actinoconchus planosulcatus* (Phillips, 1836), redescribed by Brunton (1980, p. 224, figs. 13, 14) from the lower Visean of Bolland, Yorkshire, differs from *A. paradoxus* in having a very shallow sulcus on the ventral valve.

**Occurrence.**—HK2 Unit.

**Distribution.**—Lower Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt) and Ireland (Kildare).

Genus *LAMELLOSATHYRIS* Jin and Fang, 1983

**Type species.**—*Spirifer lamellosus* Léveillé, 1835.

*Lamellosathyris qaidamensis* Chen, Shi and Zhan, 2003
(Figs. 26M, N, 27A)

*Athyris lamellosa* (Léveillé). Hall and Clarke, 1895, p. 46, figs. 16–20; Weller, 1914, p. 465, pl. 78, figs. 1–5, 15–20; Zhang et al., 1983, p. 375, pl. 124, figs. 1, 2.
*Actinoconchus* cf. *lamellosa* (Léveillé). Minato, 1951, p. 380, pl. 1, fig. 6.
*Actinoconchus lamellosa* (Léveillé). Minato, 1952, p. 173, pl. 11, fig. 6.
*Cleiothyridina lamellosa* (Léveillé). Yang, 1964, p. 144, pl. 22, figs. 1, 2.
*Athyris lamellosus* (Léveillé). Litvinovich in Litvinovich et al., 1969, p. 281, pl. 69, fig. 6.
*Actinoconchus lamellosus* (Léveillé). Minato et al., 1979a, pl. 19, fig. 1.
*Lamellosathyris lamellosa* (Léveillé). Tazawa, 1989, p. 61, pl. 1, fig. 3; Carter, 1999, p. 121, figs. 13, 14.
*Lamellosathyris qaidamensis* Chen, Shi and Zhan, 2003, p. 849, figs. 4, 5.1–5.6, 5.8, 5.9, 5.11, 5.12, 5.16, 5.17, 6.

**Material.**—Twelve specimens from locality KF202: (1) external and internal moulds of a conjoined shell, NU-B2029; (2) internal moulds of two conjoined shells, NU-B2030, 2031; (3) external moulds of four ventral valves, NU-B2032–2035; (4) internal moulds of three ventral valves, NU-B2036–2038; and (5) internal moulds of two dorsal valves, NU-B2039, 2040.

**Description.**—Shell large in size for genus, transversely subelliptical in outline; dorsibiconvex in lateral profile; cardinal extremities rounded; hinge much shorter than greatest width at midlength; length 37 mm, width 55 mm in the largest specmen (NU-B2029). Ventral valve moderately and unevenly convex in lateral profile, strongly convex in posterior half, and gently convex to nearly flat in anterior half; umbo small, slightly incurved and having large rounded foramen; interarea very narrow, convex; sulcus originating near beak, shallow and narrow, with rounded bottom. Dorsal valve a little more convex than ventral valve, with greatest convexity posterior to midlength; umbo incurved beneath opposite valve; fold low and narrow on anterior portion of valve; External surface of both valves ornamented with regular, strong concentric lamellae, numbering 2–3 in 10 mm length on ventral valve. Ventral interior with thick short dental plates, large broad teeth, poorly defined flabellate diductor scars and narrow adductor scars. Dorsal interior with small, triangular cardinal plates; spiralia directed laterally.

**Remarks.**—These specimens were described by Tazawa (1989, p. 61, pl. 1, fig. 3) as *Lamellosathyris lamellosa* (Leveillé, 1835). But the Hikoroichi specimens can be referred to *Lamellosathyris qaidamensis* Chen, Shi and Zhan, 2003, from the upper Tournaisian–lower Visean of the Qaidam Basin, Qinghai, northwestern China, on account of the large size, dorsibiconvex profile and strong broad concentric lamellae on the both ventral and dorsal valves. The type species, *Lamellosathyris lamellosa* (Léveillé, 1835), redescribed by Brunton (1980, p. 225, figs. 15–17) from the upper Tournaisian of Tournai, Belgium, differs from *L. qaidamensis* in the smaller size and in having more numerous and narrower concentric lamellae on the both valves. Shells of *Lamellosathyris* species from the lower Carboniferous of the South Kitakami Belt, *Actinoconchus* cf. *lamellosa* (Léveillé, 1835) described by Minato (1951, p. 380, pl. 1, fig. 6) from the Jumonji Stage (=middle part of the Arisu Formation) of the Shimoarisu area and *Actinoconchus lamellosa* (Léveillé, 1835) described by Minato (1952, p. 173, pl. 11, fig. 6) from the Jumonji Stage of the Shimoarisu and Yokota areas, are conspecific with *L.*

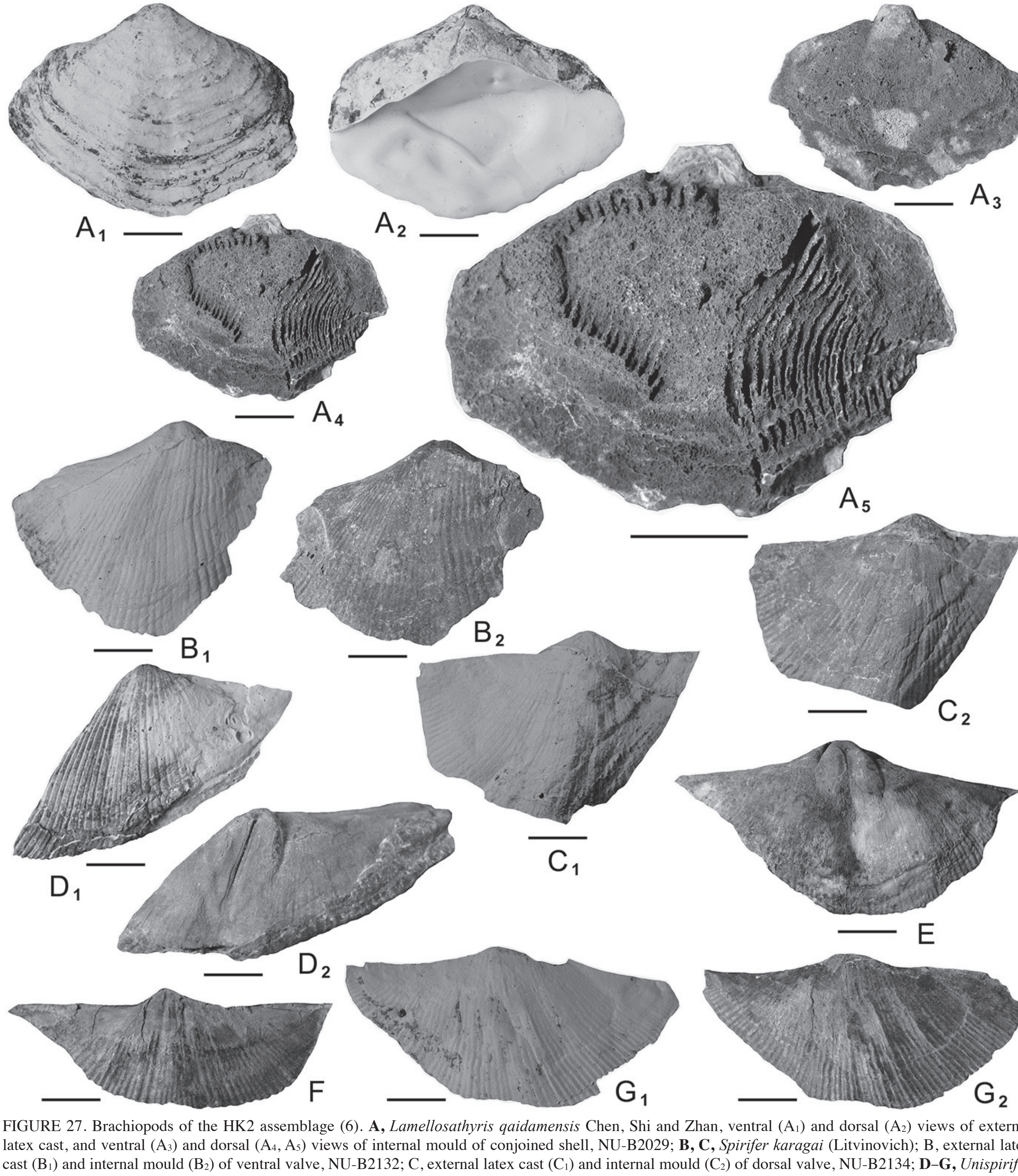


FIGURE 27. Brachiopods of the HK2 assemblage (6). **A,** *Lamellosathyris qaidamensis* Chen, Shi and Zhan, ventral ($A_1$) and dorsal ($A_2$) views of external latex cast, and ventral ($A_3$) and dorsal ($A_4$, $A_5$) views of internal mould of conjoined shell, NU-B2029; **B, C,** *Spirifer karagai* (Litvinovich); B, external latex cast ($B_1$) and internal mould ($B_2$) of ventral valve, NU-B2132; C, external latex cast ($C_1$) and internal mould ($C_2$) of dorsal valve, NU-B2134; **D–G,** *Unispirifer striatoconvolutus* (Dun and Benson); D, external latex cast ($D_1$) and internal mould ($D_2$) of ventral valve, NU-B2096; E, internal mould of ventral valve, NU-B2099; F, internal mould of dorsal valve, NU-B2101; G, external latex cast ($G_1$) and internal mould ($G_2$) of dorsal valve, NU-B2100. Scale bars represent 1 cm.

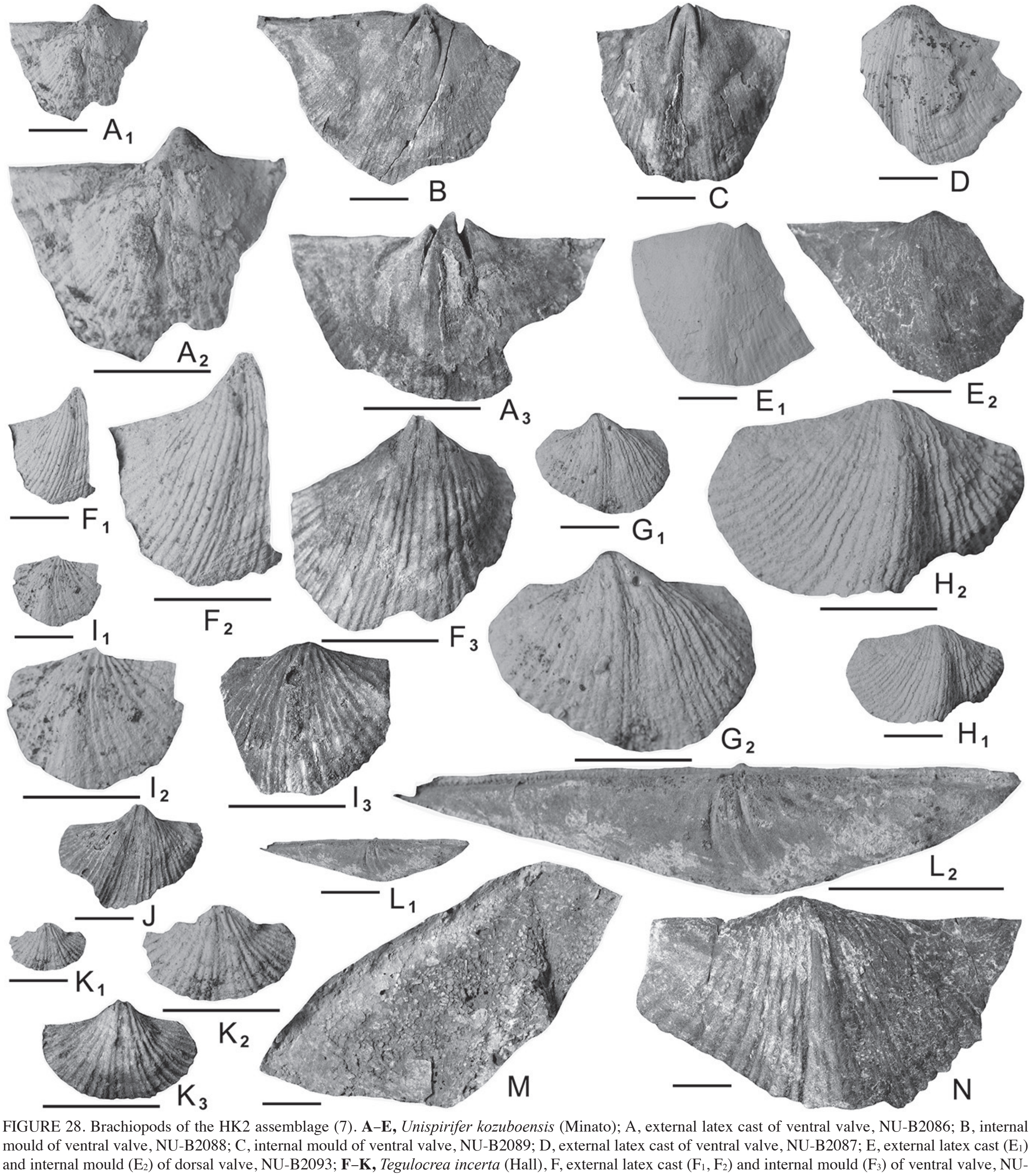


FIGURE 28. Brachiopods of the HK2 assemblage (7). **A–E,** *Unispirifer kozuboensis* (Minato); A, external latex cast of ventral valve, NU-B2086; B, internal mould of ventral valve, NU-B2088; C, internal mould of ventral valve, NU-B2089; D, external latex cast of ventral valve, NU-B2087; E, external latex cast ($E_1$) and internal mould ($E_2$) of dorsal valve, NU-B2093; **F–K,** *Tegulocrea incerta* (Hall), F, external latex cast ($F_1$, $F_2$) and internal mould ($F_3$) of ventral valve, NU-B2066; G, external latex cast of ventral valve, NU-B2071; H, external latex cast of dorsal valve, NU-B2075; I, external latex cast ($I_1$, $I_2$) and internal mould ($I_3$) of dorsal valve, NU-B2068; J, internal mould of ventral valve, NU-B2080; K, external latex cast ($K_1$, $K_2$) and internal mould ($K_3$) of ventral valve, NU-B2067; **L,** *Acuminothyris triangularis* Roberts, internal mould of dorsal valve, NU-B2121; **M, N,** *Pseudocyrinx* cf. *missouriensis* Weller; M, external mould of ventral interarea, NU-B2041; N, internal mould of dorsal valve, NU-B2108. Scale bars represent 1 cm.

*qaidamensis*.

**Occurrence.—**HK2 Unit.

**Distribution.—**Upper Tournaisian–lower Visean: northeastern Japan (Hikoroichi, Shimoarisu, and Yokota in the South Kitakami Belt), USA (Ohio, Indiana, Missouri and Oklahoma), Kazakhstan and northwestern China (Xinjiang and Qinghai).

Subfamily CLEIOTHYRIDININAE Alvarez, Rong and Boucot, 1998
Genus *CLEIOTHYRIDINA* Buckman, 1906

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

*Cleiothyridina harkeri* Carter, 1987
(Fig. 19C)

*Cleiothyridina obmaxima* (McChesney)?. Nelson, 1961, pl. 4, figs. 5, 6; pl. 7, fig. 14.
*Cleiothyridina harkeri* Carter, 1987, p. 60, pl. 19, figs. 24–27.

**Material.—**One specimen from locality KF200, internal mould of a ventral valve, with partly preserved shell substance, NU-B2201.

**Remarks.—**This specimen is referred to *Cleiothyridina harkeri* Carter (1987, p. 60, pl. 19, figs. 24–27), from the upper part of the Banff Formation of western Alberta, Canada, by the large size (length 28 mm, width about 50 mm), transversely subelliptical outline and gently convex ventral valve, with weak shallow sulcus. The external surface of the ventral valve is covered by very dense, narrow growth lamellae which are fringed with numerous flattened spines. Carter (1987, p. 60) noted that *Cleiothyridina obmaxima* (McChesney)?, figured by Nelson (1961, pl. 4, figs. 5, 6; pl. 7, fig. 14) from the Banff Formation of Alberta, is conspecific with *C. harkeri*. *Cleiothyridina royssii* (Léveillé, 1835), redescribed by Brunton (1980, p. 228, figs. 23, 24), from the upper Tournaisian of Tournai, Belgium, differs from *C. harkeri* in the smaller size and in having deeper ventral sulcus.

**Occurrence.—**HK1 Unit.

**Distribution.—**Lower–upper Tournaisian: northeastern Japan (Hikoroichi in the South Kitakami Belt) and northern Canada (Alberta).

*Cleiothyridina* sp.
(Fig, 33C)

*Cleiothyridina* sp. Tazawa, 1984b, p. 307, pl. 61, fig. 5.

**Material.—**One specimen from locality KF167, external mould of a valve fragment, IGPS97907.

**Remarks.—**The fragmentarily preserved specimen from Hikoroichi is safely assigned to the genus *Cleiothyridina* by the characteristic external ornament of regular concentric lamellae, edges of which are fringed with numerous flattened spines. But the Hikoroichi specimen is too poorly preserved for specific determination.

**Occurrence.—**HK4 Unit.

Suborder RETZIIDINA Boucot, Johnson and Staton, 1964
Superfamily RETZIOIDEA Waagen, 1883
Family NEORETZIIDAE Dagys, 1972
Subfamily HUSTEDIINAE Grunt, 1986
Genus *HUSTEDIA* Hall and Clarke, 1893

**Type species.—***Terebratula mormoni* Marcou, 1858.

*Hustedia* sp.
(Fig. 26D)

**Material.—**One specimen from locality KF202, internal mould of a ventral valve, NU-B2109.

**Remarks.—**This specimen is safely assigned to the genus *Hustedia* by the small, elongate-oval ventral valve (length about 12 mm, width about 7 mm) with shallow sulcus and the external ornament consisting of relatively few strong costae (numbering 6 on one side of lateral flanks). The Hikoroichi species most resembles *Hustedia* aff. *radialis* (Phillips, 1836), described by Nalivkin (1937, p. 120, pl. 34, figs. 5, 6) from the Kassin and Rusakov beds of northeastern Kazakhstan, in size, shape and external ornament of the ventral valve. *Hustedia radialis* (Phillips, 1836), redescribed by Brunton (1984, p. 44, figs. 30–38) from the Visean of Yorkshire, England, differs from the present species in the wider outline and more numerous costae on the ventral valve.

**Occurrence.—**HK2 Unit.

Order SPIRIFERIDA Waagen, 1883
Suborder SPIRIFERIDINA Waagen, 1883
Superfamily SPIRIFEROIDEA King, 1846
Famiy SPIRIFERIDAE King, 1846
Subfamily SPIRIFERINAE King, 1846
Genus *SPIRIFER* Sowerby, 1816

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

*Spirifer liangchowensis* Chao, 1929
(Fig. 31G)

*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, 2017b, p. 340, figs. 8.1–8.5.
*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.
*Spirifer* sp. Tazawa, 1984b, p. 307, pl. 61, fig. 1.

**Material.—**One specimen from locality KF151, an imperfect conjoined shell, IGPS97908.

**Remarks.—**The single specimen from Hikoroichi was described by Tazawa (1984b, p. 307, pl. 61, fig. 1) as *Spirifer* sp. But the specimen can be referred to *Spirifer liangchowensis* Chao (1929, p. 6, pl. 1, figs. 1–7, text-fig. 1), from the Chouniugou Formation of Gansu, northwestern China, on account of the average-sized, less transverse shell (length more than 39 mm, width about 50 mm), with narrow and deep but not clearly demarcated ventral sulcus. The Hikoroichi specimen resembles well the shells, described by Tazawa (2017b, p. 340, figs. 8.1–8.5) as *S. liangchowensis* from the uppermost part of the Odaira Formation (upper Visean) in the Yokota area, South Kitakami Belt. *Spirifer karagai* (Litvinovich, 1962, p. 273, pl. 33, fig. 2), from the upper Visean of central Kazakhstan, resembles *S. liangchowensis* in size and outline of the shell, but differs from the latter in having shallower ventral sulcus and lower dorsal fold.

**Occurrence.**—HK4 Unit.

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

*Spirifer karagai* (Litvinovich, 1962)
(Fig. 27B, C)

*Neospirifer karagai* Litvinovich, 1962, p. 273, pl. 33, fig. 2.
*Spirifer karagai* (Litvinovich). Litvinovich et al., 1969, p. 259, pl. 62, figs. 1–4.

**Material.**—Four specimens from locality KF202: (1) external and internal moulds of a ventral valve, NU-B2132; (2) internal mould of a ventral valve, NU-B2133; (3) external and internal moulds of a dorsal valve, NU-B2134; and (4) internal mould of a dorsal valve, NU-B2135.

**Description.**—Shell medium in size for genus, slightly transverse, subrectangular in outline, widest at hinge; cardinal extremities blunt, angular, not mucronate; length 38 mm, width about 58 mm in the largest specimen (NU-B2132). Ventral valve strongly and unevenly convex in lateral profile, most convex in umbonal region; umbo small, strongly incurved; sulcus narrow and shallow, not clearly demarcated from flanks. Dorsal valve less inflated than ventral valve, moderately convex in umbonal region and flanks, flattened near cardinal extremities; fold narrow and low, defined by fold-bounding grooves. External surface of both valves ornamented with numerous, fine, rounded and bifurcating costae, irregular concentric rugae and very fine numerous growth lines; costae numbering 4–5 in 5 mm at midlength of ventral flanks. Internal structures of both valves not well preserved.

**Remarks.**—These specimens are referred to *Spirifer karagai* (Litvinovich, 1962, p. 273, pl. 33, fig. 2), from the upper Visean of central Kazakhstan, on account of the middle-sized, less transverse shell, with shallow ventral sulcus and low dorsal fold. The preceding species, *Spirifer liangchowensis* Chao (1929), is distinguished from *S. karagai* in possessing deeper ventral sulcus and higher 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. karagai* in having longer shell with shorter hinge.

**Occurrence.**—HK2 Unit.

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

Subfamily PROSPIRINAE Carter, 1974
Genus *UNISPIRIFER* Campbell. 1957

**Type species.**—*Spirifer striatoconvolutus* Dun and Benson, 1920.

*Unispirifer striatoconvolutus* (Dun and Benson, 1920)
(Fig. 27D–G)

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

**Material.**—Eight specimens from locality KF202: (1) external and internal moulds of two ventral valves, NU-B2095, 2096; (2) external moulds of two ventral valves, NU-B2097, 2098; (3) internal mould of a ventral valve, NU-B2099; (4) external and internal moulds of two dorsal valves, NU-B2100, 2101; and (5) internal mould of a dorsal valve, NU-B2102.

**Description.**—Shell large in size for genus, transversely semicircular in outline, with greatest width at hinge, cardinal extremities mucronate; length 32 mm, width about 70 mm in the largest ventral valve specimen (NU-B2097). Ventral valve moderately convex in lateral profile, most convex at umbonal region; umbo small, incurved; sulcus narrow and shallow in posterior half, becoming broader and not clearly demarcated from flanks anteriorly. Dorsal valve less convex than opposite valve; fold very shallow, indistinct. External surface of both valves ornamented with numerous moderately strong costae, few irregular concentric rugae and very fine closely spaced growth lines; costae flatly rounded, simple on flanks and often bifurcated on both sulcus and fold, numbering 7–8 costae in 10 mm at anterior margin of ventral flanks. Ventral interior with stout divergent dental plates and heart-shaped muscle field. Dorsal interior not well preserved.

**Remarks.**—These specimens are referred to *Unispirifer striatoconvolutus* (Dun and Benson, 1920), redescribed by Campbell (1957, p. 68, pl. 14, figs. 1–9, text-figs. 10–12) from the Merlewood Formation of Babbinboon, New South Wales, eastern Australia, on account of the large, transverse and mucronate shells with very shallow ventral sulcus and low indistinct dorsal fold. *Unispirifer fluctuosus* (Glenister, 1955, p. 68, pl. 7, figs. 1–14; pl. 8, fig. 1–8), from the Moogooree Limestone of the North-West Basin, western Australia, resembles *U. striatoconvolutus* in general shape, but differs in the smaller size and in having coarser costae on the both valves.

**Occurrence.**—HK2 Unit.

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

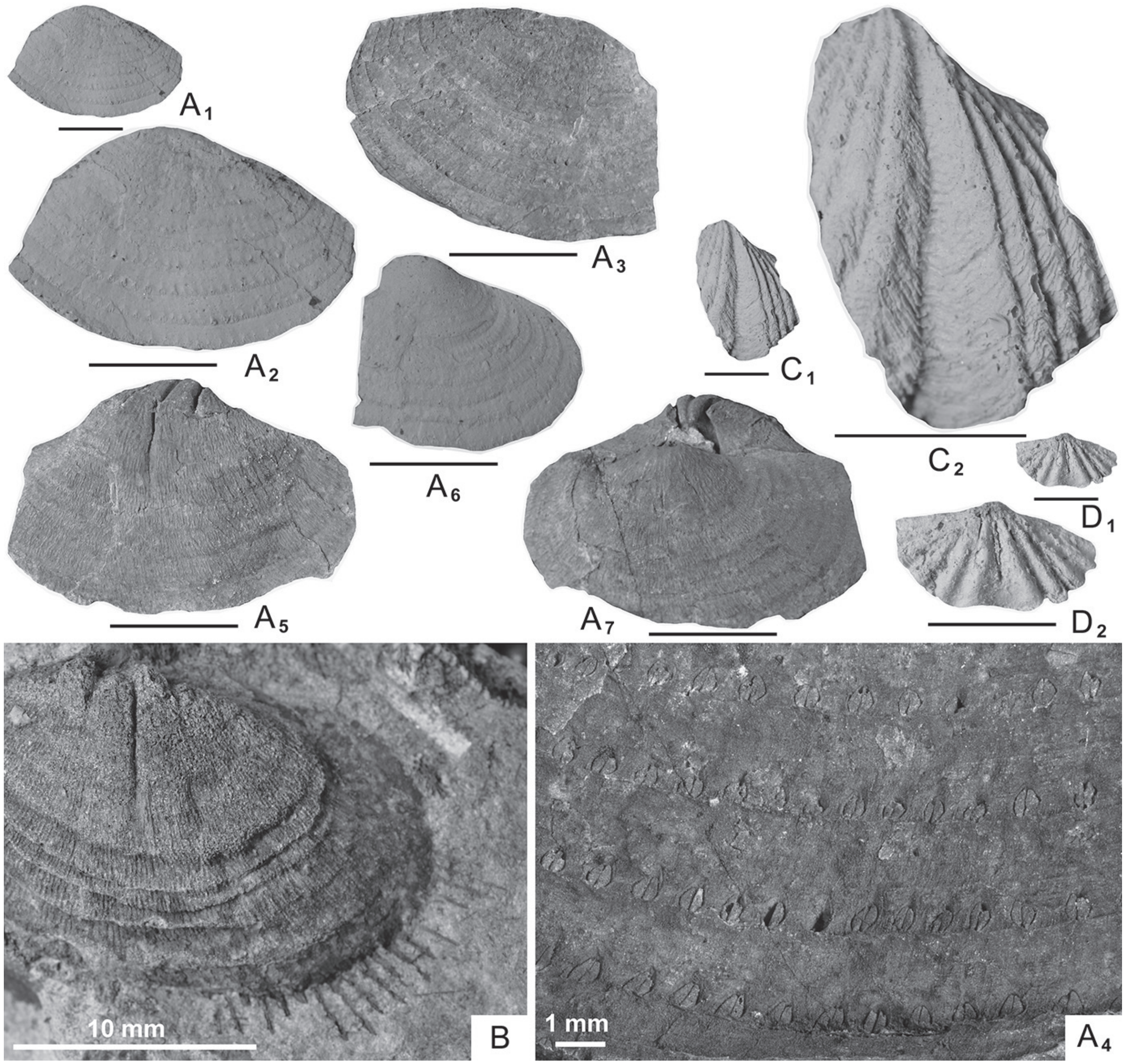


FIGURE 29. Brachiopods of the HK2 assemblage (8). **A, B,** *Kitakamithyris hikoroitiensis* Minato; A, external latex cast ($A_1$, $A_2$), external moud ($A_3$), enlarged concentric rows of biramous spine bases ($A_4$) and internal mould ($A_5$) of ventral valve, and external latex cast ($A_6$) and internal mould ($A_7$) of dorsal valve in a conjoined shell, NU-B2084; B, internal mould of ventral valve, showing numerous spines on the antero-lateral margins of the valve, NU-B2085; **C,** *Punctospirifer gigantiformis* Lee and Gu, external latex cast of ventral valve, NU-B2107; **D,** *Punctospirifer plicatosulcatus* Glenister, external latex cast of ventral valve, NU-B2106. Scale bars represent 1 cm, unless otherwise specified.

*Unispirifer mediocris* (Tolmatchoff, 1924)
(Fig. 19G–J)

*Spirifer mediocris* Tolmatchoff, 1924, p. 181, 561, pl. 11, figs. 13, 14.

*Spirifer* (*Spirifer*) *marionensis* Shumard. Nalivkin, 1937, p. 100, pl. 28, fig. 1.

*Fusella mediocris* (Tolmatchoff). Besnossova, 1959, p. 71, pl. 3, fig. 10; pl. 11, fig. 10; text-figs. 24, 25; Besnossova in Sarytcheva et al., 1963, p. 289, pl. 52, fig. 8; Abramov, 1965, p. 48, pl. 9, fig. 1; Abramov, 1970, p. 137, pl. 25, figs. 12–17; Kalashnikov, 1974, p. 121, pl. 40, figs. 5, 6, text-fig. 21; Litvinovich et al., 1975, p. 89, pl. 28, figs. 12, 13.

*Unispirifer*? *corpulentus* Carter, 1968, p. 1149, pl. 147, figs. 10–22.

**Material.**—Four specimens from locality KF201: (1) internal moulds of two ventral valves, NU-B2209, 2210; and (2) internal moulds of two ventral valves, NU-B2211, 2212.

**Description.**—Shell small in size for genus, slightly transverse subelliptical in outline, with greatest width at hinge; length 26 mm, width 34 mm in the better preserved dorsal valve specimen (NU-B2212). Ventral valve moderately convex in lateral slopes; umbo small, incurved; ears small, mucronate; interarea subtrigonal, concave; sulcus shallow, bearing four or five sulcul costae; lateral flanks ornamented with numerous simple rounded costae. Dorsal valve gently convex in lateral profile; fold low but clearly demarcated from lateral slopes; lateral slopes ornamented with numerous rounded costae on whole valve and a few strong irregular concentric rugae near anterior margin. Interior of ventral valve with stout diverging dental plates, enclosing posteriror portion of muscle field. Internal structure of dorsal valve not well preserved.

**Remarks.**—These specimens are referred to *Unispirifer mediocris* (Tolmatchoff, 1924, p. 181, 561, pl. 11, figs. 13, 14), from the Tournaisian of the Kuznetsk Basin, on account of size, shape and external ornament of both ventral and dorsal valves, in particular, the shallow ventral sulcus, low dorsal fold and mucronate cardinal extremities. *Unispirifer*? *corpulentus* Carter (1968, p. 1149, pl. 147, figs. 10–22), from the Burlington Limestone of Missouri, is deemed a junior synonym of *U. mediocris*. *Unispirifer kozuboensis* (Minato, 1952, p. 155, pl. 5, fig. 7), from the Jumonji Stage of the Yokota area, South Kitakami Belt, differs from *U. mediocris* in the larger size and more transverse outline.

**Occurrence.**—HK1 Unit.

**Distribution.**—Lower Tournaisian–lower Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt), USA (Missouri), northern Russia (Verkhoyansk Range and northern Urals), central Russia (Kuznetsk Basin) and Kazakhstan.

*Unispirifer kozuboensis* (Minato, 1952)
(Fig. 28A–E)

*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.

**Material.**—Nine specimens from locality KF202: (1) external and internal moulds of a ventral valve, NU-B2086; (2) external mould of a ventral valve, NU-B2087; (3) internal moulds of five ventral valves, NU-B2088–2092; and (4) external and internal moulds of two dorsal valves, NU-B2093, 2094.

**Description.**—Shell medium in size for genus, transversely subtrigonal in outline, with greatest width at hinge; cardinal extremities mucronate; length about 35 mm, width about 60 mm in the largest specimen (NU-B2088). 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, produced, triangular and nearly flat. Dorsal valve gently convex in both lateral and anterior profiles; fold narrow and low, clearly demarcated from lateral flanks by a pair of distinct grooves in juveniles, but indistinct in adults. External surface of both valves ornamented with numerous moderately strong costae, irregular concentric rugae and very fine closely spaced growth lines; costae becoming broad and flat anteriorly, mostly simple but rarely bifurcated; numbering 7–8 in 10 mm on lateral flanks near anterior margin of ventral valve. Ventral interior with stout divergent dental plates. Dorsal interior not well preserved and obscure.

**Remarks.**—These specimens are referred to *Unispirifer kozuboensis* (Minato, 1952), originally described by Minato (1952, p. 155, pl. 5, fig. 7) as *Spirifer kozuboensis* from the Arisu Formation of Kozubo (Otsubo), Yokota area, South Kitakami Belt, in size, shape and external ornament of both valves, particularly, in having mucronate cardinal extremities. *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 differs from the Kitakami species in the larger dimensions and in possessing less numerous, stronger costae on the both valves.

**Occurrence.**—HK2 Unit.

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

Family CHORISTITIDAE Waterhouse, 1968
Subfamily ANGIOSPIRIFERINAE Legrand-Blain, 1985
Genus *ANGIOSPIRIFER* Legrand-Blain, 1985

**Type species.**—*Spirifer trigonalis* Martin, 1809.

*Angiospirifer bisulcatus* (Sowerby, 1825)
(Fig, 31F)

*Spirifer bisulcatus* Sowerby, 1825, p. 152, pl. 494, figs. 1, 2; Scupin, 1900, p. 315, pl. 10, fig. 6; Gröber, 1908, p. 222, 239, pl. 26, figs. 3, 8–10, text-figs. 3, 4; Yanishevsky, 1918, p. 82, pl. 6, figs. 1, 15 only; Frech, 1916, p. 252, pl. 8, fig. 7; Grabau, 1924, p. 238, text-fig. 152; Rotai, 1931, p. 78, pl. 6, figs. 3–5; Grabau, 1931, p. 26, fig. 6; Demanet, 1938, p. 88, pl. 8, figs. 17–19; Dedok and Tschernjak, 1960, p. 65, pl. 8, fig. 3; Litvinovich, 1962, p. 279, pl. 35, fig. 2; Litvinovich et al., 1969, p. 262, pl. 72, figs. 2–4; Volgin, 1965, p. 53, pl. 3, figs. 7, 8.
*Spirifera bisulcata* (Sowerby). Davidson, 1858, p. 31, pl. 5, fig. 1; pl. 6, figs. 6–16 only; Dun and Benson, 1920, p. 347, pl. 21, fig. 1.
*Spirifer trigonalis* var. *bisulcatus* Sowerby. Gröber, 1909, p. 366, pl. 3, figs. 2, 4.
*Choristites bisulcatus* (Sowerby). Grabau, 1932, p. 96, pl. 2, fig. 13; Mori and Tazawa, 1980, text-fig. 3.1; Tazawa, 1984b, p.

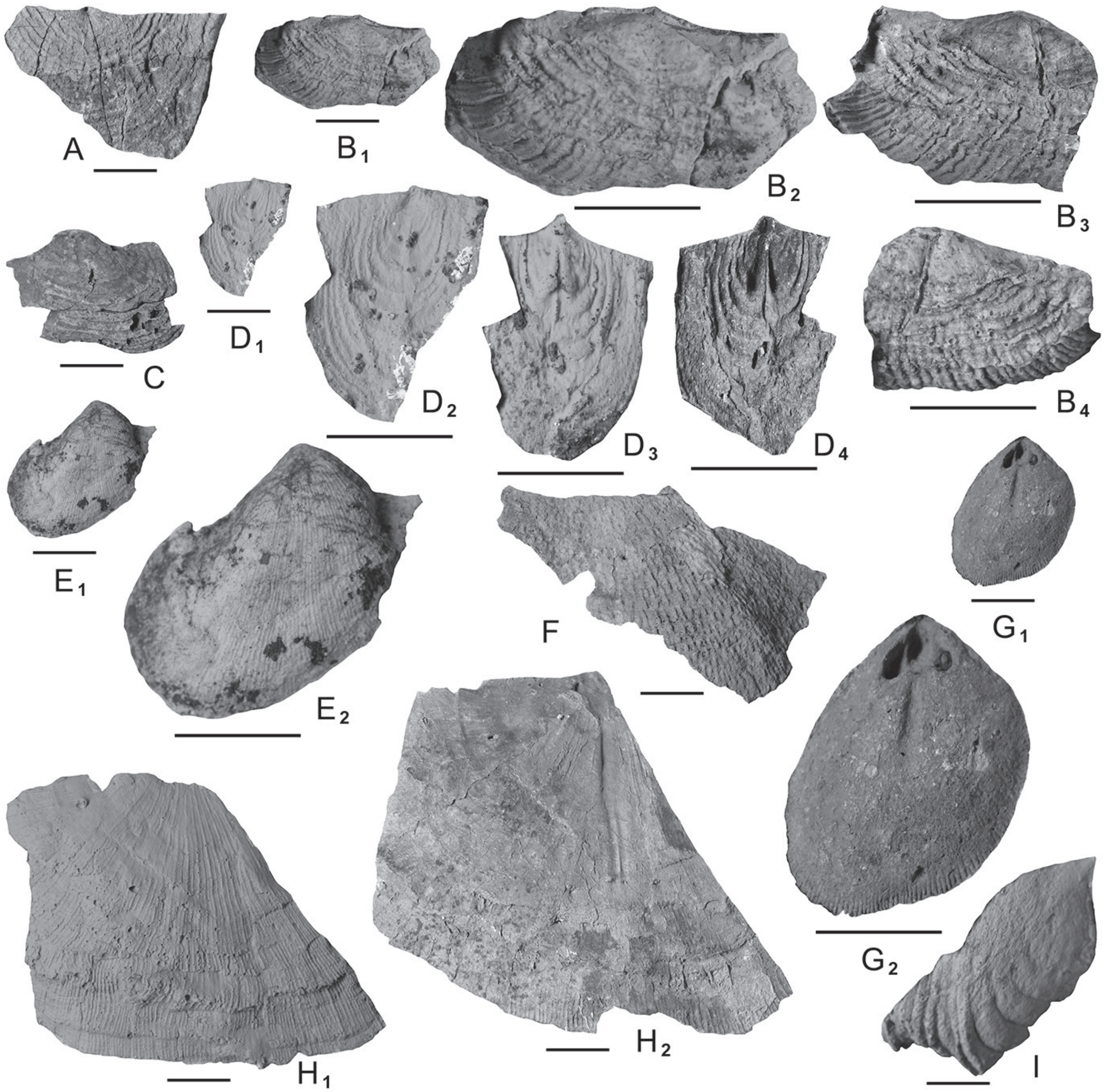


FIGURE 30. Brachiopods of the HK4 assemblage (1). **A,** *Leptagonia analoga* (Phillips), external mould of dorsal valve, NU-B2239; **B,** *Argentiproductus margaritaceus* (Phillips), external latex cast ($B_1$, $B_2$), internal mould ($B_3$) and internal latex cast ($B_4$) of dorsal valve, NU-B2235; **C, D,** *Karavankina jizodoensis* Tazawa; C, internal mould of ventral valve, NU-B2233; D, external latex cast ($D_1$, $D_2$), internal latex cast ($D_3$) and internal mould ($D_4$) of dorsal valve, IGPS97905; **E,** *Ovatia* cf. *prolata* Carter, external latex cast of ventral valve, NU-B2232; **F,** *Pustula pustulosa* (Phillips), external mould of dorsal valve, IGPS97904; **G,** *Rhipidomella michelini* (Léveillé), internal mould of dorsal valve, IGPS97902; **H,** *Orthotetes keokuk* (Hall), external latex cast ($H_1$) and internal mould ($H_2$) of dorsal valve, IGPS97903; **I,** *Rotaia hikoroichiensis* Tazawa, external latex cast of fragmented ventral valve, NU-B2227. Scale bars represent 1 cm.

308, pl. 61, fig. 4.

*Spirifer* ex gr. *bisulcatus* Sowerby. Korejwo, 1986, pl. 9, fig. 6; Abramov, 1970, p. 142, pl. 22, fig. 8.

*Angiospirifer bisulcatus* (Sowerby). Angiolini et al., 2011, p. 74, figs. 1, 2, 6.

**Material.**—One specimen from locality KF153, external and internal moulds of a ventral valve, IGPS97909.

**Description.**—Shell medium in size for genus, wider subtrigonal in outline, with greatest width at hinge; length 28 mm, width 34 mm in the sole specimen (IGPS97909). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region; umbo narrow, incurved; cardinal extremities blunt, produced; sulcus narrow, moderately deep and having a pair of simple primary costae and 1 or 2 simple costae on outside the primary costae. External surface of ventral lateral slopes ornamented with numerous rounded costae with narrow intercostal grooves; costae mostly simple but a few of them bifurcated near anterior valve margin, numbering 9 costae on each lateral slope. Interior of ventral valve not well preserved. Shell substance thick at umbonal region.

**Remarks.**—This specimen was described by Tazawa (1984b, p. 308, pl. 61, fig. 4) as *Choristites bisulcatus* (Sowerby, 1825). But the genus of the species is now assigned to *Angiospirifer* Legrand-Blain, 1985. *Angiospirifer bisulcatus* most resembles *Angiospirifer pseudobisulcatus* Rotai (1951, p. 48, pl. 7, fig. 9; pl. 8, figs. 1, 2), from the lower Bashkirian of the Donetz Basin, western Russia, but the Russian species differs from the present species in having less produced cardinal extremities. The type species, *Angiospirifer trigonalis* (Martin, 1809), is readily distinguished from *A. bisulcatus* in having anteriorly elevated dorsal fold.

**Occurrence.**—HK4 Unit.

**Distribution.**—Upper Visean–Bashkirian: northeastern Japan (Hikoroichi in the South Kitakami Belt), northern Russia (Verkhoyansk Range and Taimyr Peninsula), UK (Scotland, England, Isle of Man and northern Ireland), Belgium, Germany, Poland, western Russia (Donetz Basin), Kazakhstan, Uzbekistan, Kyrgyzstan, northwestern China (Xinjiang) and eastern Australia (New South Wales).

Family IMBREXIIDAE Carter, 1992
Genus *TEGULOCREA* Carter, 1992

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

*Tegulocrea incerta* (Hall, 1858)
(Fig. 28F–K)

*Spirifer incertus* Hall, 1858, p. 602, pl. 13, fig. 3.
*Tegulocrea incerta* (Hall). Carter, 1992, p. 331, figs. 3, 4; Carter, 1999, p. 125, figs. 18A–D.

**Material.**—Fifteen specimens from locality KF202: (1) external and internal moulds of two ventral valves, NU-B2066, 2067; (2) external and internal moulds of a dorsal valve, NU-B2068; (3) external moulds of five ventral valves, NU-B2069, 2071–2074; (4) external moulds of three dorsal valves, NU-B2070, 2075, 2076; and (5) internal moulds of four ventral valves, NU-B2077–2080.

**Description.**—Shell small to medium in size for genus, transversely semicircular to subquadrate in outline, with greatest width at slightly anterior to hinge; cardinal extremities obtuse to blunt, angular; length 19 mm, width 31 mm in the largest dorsal valve specimen (NU-B2075); length 18 mm, width 22 mm in the average-sized ventral valve specimen (NU-B2071). Ventral valve strongly convex in lateral profile; umbo small, incurved; sulcus narrow and moderately deep; lateral slopes gently convex. Dorsal valve slightly less convex than opposite valve; fold narrow and moderately high; lateral slopes gently convex to nearly flat. Entire surface of both valves ornamented with numerous fine imbricate costae; costae often bifurcate, numbering 7–9 costae in 5 mm at about midlength of ventral lateral slope; imbricate growth lamellae regularly developed. Ventral interior with short, strong dental adminicula. Other internal structures of both valves not well preserved.

**Remarks.**—These specimens are referred to *Tegulocrea incerta* (Hall, 1858), redescribed by Carter (1992, p. 331, figs. 3, 4) from the St. Joe Formation (upper Tournaisian) of Kenwood, Mayes County, Oklahoma, in the small to medium size, wider semicircular to subquadrate outline and in possessing numerous fine imbricate costae on both valves. Shells described by Minato and Kato (1977, p. 614, pl. 1, figs. 2–11) as *Imbrexia* cf. *incertus* (Hall) from the upper part of the Hikoroichi Formation (= Karoyama Formation of Tazawa et al., 1981) at north of Karoyama, Nisawa area, South Kitakami Belt, differs from the present species by the much larger dimensions. *Tegulocrea tenuicostata* (Hall, 1858), redescribed by Weller (1914, p. 328, pl. 42, figs. 4–16) from the Keokuk, Warsaw and Salem Formations of the Mississippi Valley, is distinguished from *T. incerta* by the larger size and more transverse outline.

**Occurrence.**—HK2 Unit.

**Distribution.**—Upper Tournaisian–lower Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt) and USA (Iowa and Oklahoma).

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

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

*Acuminothyris triangularis* Roberts, 1963
(Fig. 28L)

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

**Material.**—One specimen from locality KF202, internal mould of a dorsal valve, NU-B2121.

**Remarks.**—The Hikoroichi specimen 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 8 mm, width 37 mm), very transverse outline and external ornament of the dorsal valve, consisting of numerous costae and fine numerous concentric growth lamellae. The single ventral valve specimen, described by Minato and Kato

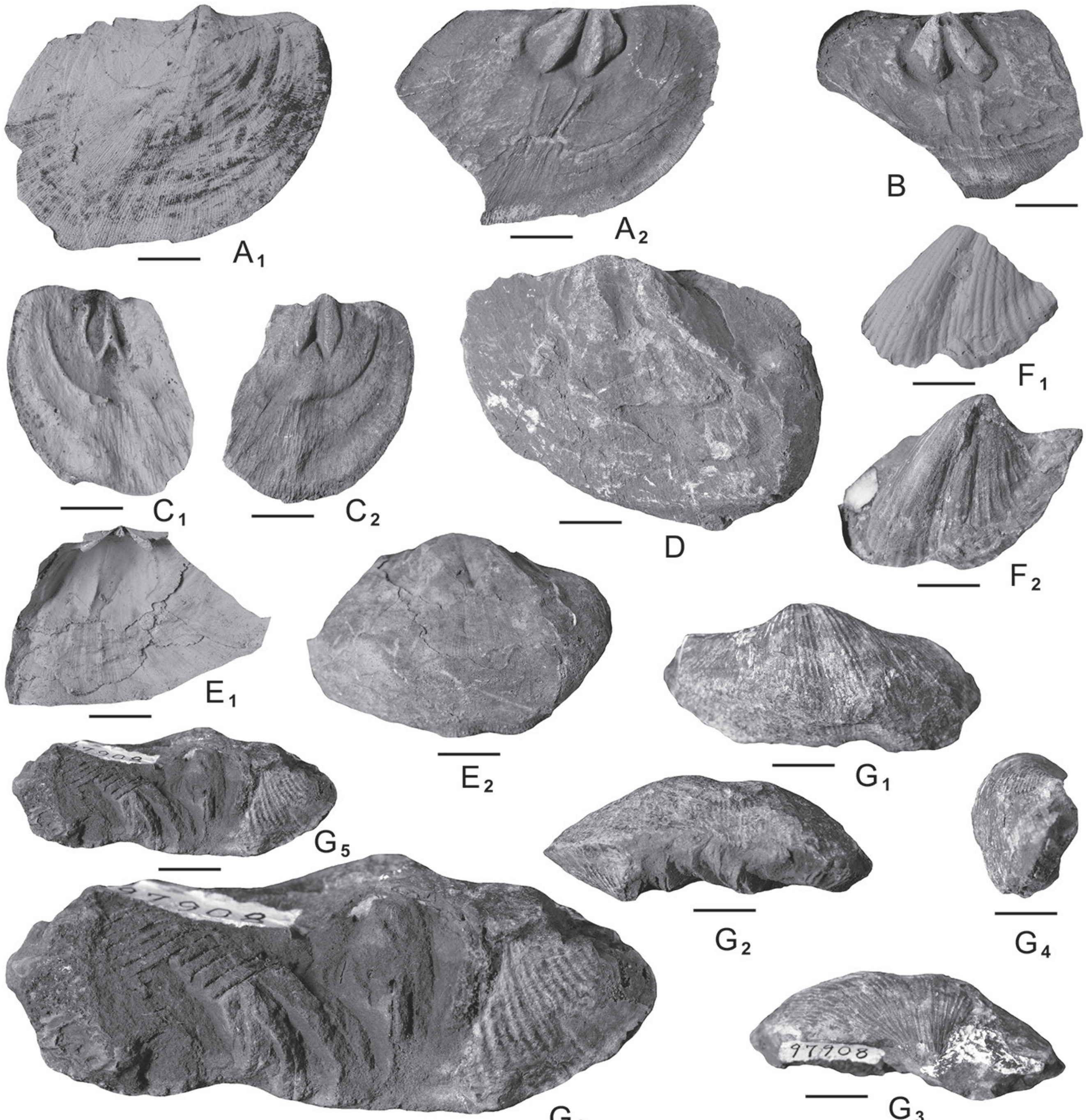


FIGURE 31. Brachiopods of the HK4 assemblage (2). **A–E,** *Schizophoria resupinata* (Martin); A, external latex cast ($A_1$) and internal mould ($A_2$) of ventral valve, NU-B2218; B, internal mould of ventral valve, NU-B2219; C, internal latex cast ($C_1$) and internal mould ($C_2$) of ventral valve, NU-B2222; D, internal nould of dorsal valve, NU-B2225; E, internal latex cast ($E_1$) and internal mould ($E_2$) of dorsal valve, NU-B2226; **F,** *Angiospirifer bisulcatus* (Sowerby), external latex cast ($F_1$) and internal mould ($F_2$) of ventral valve, IGPS97909; **G,** *Spirifer liangchowensis* Chao, ventral ($G_1$), anterior ($G_2$), posterior ($G_3$), lateral ($G_4$) and interior ($G_5$, $G_6$) views of conjoined shell, IGPS97908. Scale bars represent 1 cm.

(1977, p. 615, pl. 1, fig. 1) as "*Spirifer*" *mundulus* Rowley (1893) from the lower part of the Hikoroichi Formation at Omori in the Hikoroichi area, is identical with the present species in size, shape and external ornament of the ventral valve.

**Occurrence.**—HK2 Unit.

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

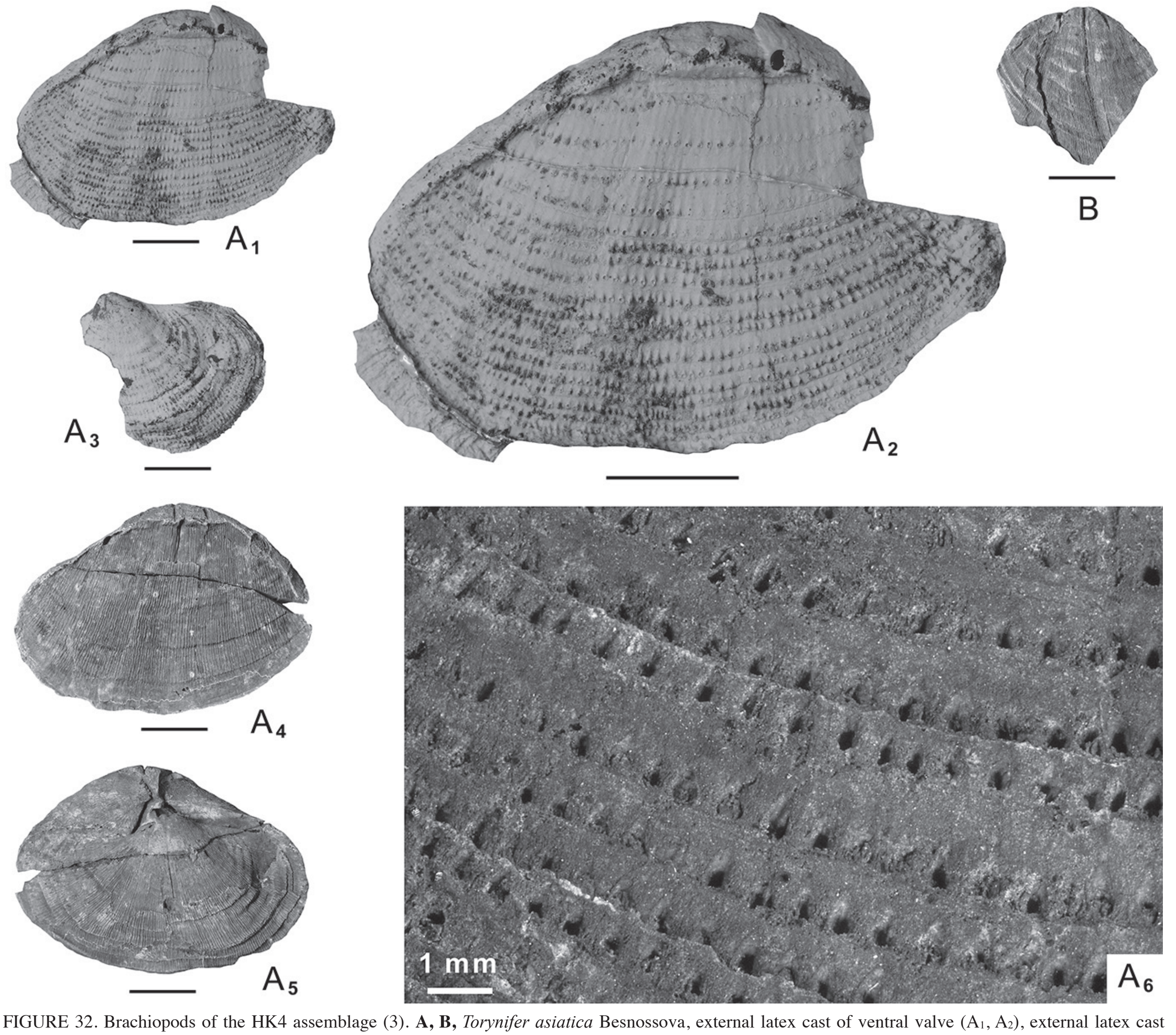


FIGURE 32. Brachiopods of the HK4 assemblage (3). **A, B,** *Torynifer asiatica* Besnossova, external latex cast of ventral valve ($A_1$, $A_2$), external latex cast of dorsal valve ($A_3$), internal mould of ventral valve ($A_4$), internal mould of dorsal valve ($A_5$) and enlarged concentric rows of biromous spine bases on the external mould of ventral valve of conjoined shell, NU-B2228; B, internal mould of ventral valve, NU-B2229. Scale bars represent 1 cm, unless otherwise specified.

*Acuminothyris keokuk* Carter, 1990
(Fig. 19D–F)

*Acuminothyris keokuk* Carter, 1990, p. 236, figs. 8.1–8.9; Chen and Archbold, 2000, p. 193, figs. 5.1–5.4.

**Material.**—Six specimens from locality KF201: (1) an abraded conjoined shell, NU-B2115; (2) external mould of a conjoined shell, NU-B2116; (3) internal mould of a conjoined shell, NU-B2117; (4) external and internal moulds of a ventral valve, NU-B2118; (5) internal mould of a ventral valve, NU-B2119; and (6) external and internal moulds of a dorsal valve, NU-B2120.

**Description.**—Shell medium in size for genus, transversely fusiform in outline, widest at hinge; cardinal extremities subangular, alate; length 11 mm, width about 28 mm in the largest specimen (NU-B2120). Ventral valve moderately convex in lateral profile; umbo small, incurved; interarea low, concave; lateral flanks flattened; sulcus narrow and deep, with prominent sulcus-bounding costae, Dorsal valve moderately convex as opposite valve; fold narrow and low, but well differentiated. External surface of ventral valve ornamented with simple rounded costae and fine concentric lamellae; numbering 11–12 costae on each flank; 8–9 lamellae in 3 mm. External ornament of dorsal valve same as ventral valve. Internal structures of both valves not well preserved.

**Remarks.**—These specimens are referred to *Acuminothyris keokuk* Carter (1990, p. 236, figs. 8.1–8.9), from the Keokuk Limestone of Missouri, in size, shape and external ornament of the both ventral and dorsal valves. The type species, *Acuminothyris triangularis* Roberts (1963, p. 15, pl. 5, figs. 1–8, text-figs. 7, 8) from the upper Tournaisian of New South Wales, eastern Australia, differs from *A. keokuk* in the larger and more transverse shell.

**Occurrence.**—HK1 Unit.

**Distribution.**—Upper Tournaisian–lower Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt), USA (Missouri) and northwestern China (Xinjiang).

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

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

*Brachythyris suborbicularis* (Hall, 1858)
(Fig. 19L)

*Spirifer suborbicularis* Hall, 1858, p. 644.

*Brachythyris suborbicularis* (Hall). Weller, 1914, p. 374, pl. 61, figs. 1–8; pl. 62, figs. 1–12; Nalivkin, 1937, p. 111, pl. 27, figs. 5, 11, 12; Lapina, 1962, p. 136, pl. 3, fig. 1; Abramov, 1965, p. 53, pl. 9, fig. 6; Abramov, 1970, p. 150, pl. 22, figs. 4–7; Nalivkin and Fotieva, 1973, p. 70, pl. 23, figs. 1–3; Garanj et al., 1975, p. 198, pl. 91, fig. 3; Nalivkin, 1979, p. 141, pl. 52, figs. 3, 4, 8; pl. 56, fig. 2.

**Material.**—One specimen from locality KF201, internal mould of a dorsal valve, NU-B2206.

**Remarks.**—This specimen can be referred to *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 the Mississippi Valley, by the medium to large size (length more than 30 mm, width about 40 mm), slightly wider orbicular outline and gently convex dorsal valve, with low and wide fold and 5–6 simple, broad and rounded costae on each side of lateral slope. *Brachythyris chouteanensis* Weller (1909, p. 305, pl. 13, fig. 11), from the Chouteau Limestone of Missouri, differs from *B. suborbicularis* in the smaller size and in having lower ventral interarea.

**Occurrence.**—HK1 Unit.

**Distribution.**—Upper Tournaisian–upper Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt), USA (Indiana, Iowa and Missouri), northern Russia (Verkhoyansk Range), central Russia (western Urals and southern Urals) and Kazakhstan.

Suborder DELTHYRIDINA Ivanova, 1972
Superfamily DELTHYRIDOIDEA Phillips, 1841
Family MUCROSPIRIFERIDAE Boucot, 1959
Subfamily TYLOTHYRIDINAE Carter, 1972
Genus *TYLOTHYRIS* North, 1920

**Type species.**—*Cyrtia laminosa* M'Coy, 1844.

*Tylothyris laminosa* (M'Coy, 1844)
(Fig. 19K)

*Cyrtia laminosa* M'Coy, 1844, p. 137, pl. 21, fig. 4.

*Spirifera laminosa* (M'Coy). Davidson, 1858, p. 36, pl. 7, figs. 17–19 only; Garwood, 1916, pl. 15, figs. 2, 3.

*Syringothyris laminosa* forma 2 Vaughan, 1915, p. 43, pl. 6, figs. 1–3.

*Tylothyris laminosa* (M'Coy). North, 1920, p. 197, pl. 13, figs. 1, 2, 12, 13, 16, text-figs. 1m, n, 4a, b; Dehée, 1929, p. 23, pl. 3, figs. 12–14; Plodowski, 1970, p. 21, pl. 1, figs. 3, 4, text-fig. 9; Nalivkin, 1979, p. 131, pl. 49, fig. 15; Brunton, 1984, p. 77, figs. 108–119; Tazawa et al., 1984, p. 355, pl. 67, figs. 8–11; Sun and Baliński, 2011, p. 833, figs. 7C, 31.

*Spirifer* (*Tylothyris*) *laminosa* (M'Coy). Nalivkin, 1937, p. 109, pl. 33, figs. 3, 4.

*Delthyris* aff. *clarksvillensis* (Winchell). Minato, 1952, p. 162, pl. 7, figs. 2, 5.

*Spirifer* (*Tylothyris*) *laminosa* (M'Coy). Simorin, 1956, p. 189, pl. 18, figs. 12, 13.

*Delthyris clarksvillensis* (Winchell). Minato et al., 1979a, pl. 17, fig. 4.

*Tylothyris laminosa laminosa* (M'Coy). Bassett and Bryant, 2006, p. 518, pl. 12, figs. 1–6; pl. 14, figs. 1–18: pl. 11. figs. 1–19: pl. 16, figs. 1, 2.

**Material.**—One specimen from locality KAC3, internal mould of a dorsal valve, NU-B2205.

**Remarks.**—The material available is lacking the ventral valve, but it resembles well the specimens of *Tylothyris laminosa* (M'Coy, 1844), redescribed by Brunton (1984, p. 77, figs. 108–119) from the upper Visean of County Fermanagh, northern Ireland. The single specimen from Hikoroichi is characterized by the medium size (length 16 mm, width 29 mm), transverse outline, moderately convex dorsal valve with seven or more costae on either side of prominent fold and partly preserved ornament consisting of regular lamellose growth lines. *Delthyris* aff. *clarksvillensis* (Winchell), described by Minato (1952, p. 162, pl. 7, figs. 2, 5) from the Hikoroichi Series (= Karoyama Formation of Tazawa et al., 1981) at 808 m hill, Okuhinotsuchi in the South Kitakami Belt, is considered to be a synonym of the present species. *Tylothyris transversa* Roberts (1971, p. 224, pl. 50, figs. 1–19), from the upper Tournaisian of the Bonaparte Gulf Basin, northwestern Australia, differs from *T. laminosa* in being shorter and more transverse outline.

**Occurrence.**—HK1 Unit.

**Distribution.**—Upper Tournaisian–upper Visean: northeastern Japan (Hikoroichi, Shimoarisu, Okuhinotsuchi and Soma in the South Kitakami Belt), UK (England and northern Ireland), Belgium, Afghanistan, central Russia (western Urals), Kazakhstan and southwestern China (Guizhou).

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

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

*Kitakamithyris tyoanjiensis* Minao, 1951
(Figs. 20A, 21A)

*Torynifer* (*Kitakamithyris*) *tyoanjiensis* Minato, 1951, p. 374, pl. 1, fig. 3; pl. 4, fig. 7.
*Kitakamithyris tyoanjiensis* Minato, 1952, p. 170, pl. 6, fig. 5; pl. 9, fig. 4; Minato, 1953, text-fig. 2; Minato et al., 1979a, pl. 17, fig. 1.

**Material.—**Four specimens from localities KF200 and KF201: (1) external and internal moulds of a ventral valve, NU-B2191; and (2) external moulds of three valves (ventral valve or dorsal valve unclear), NU-B2192, 2203, 2204.

**Description.—**Shell medium to large in size for genus, subelliptical in outline, with greatest width slightly anterior to midlength; length about 28 mm, width about 27 mm in the best preserved specimen (NU-B2191). Ventral valve gently and unevenly convex in lateral profile, most convex in umbonal region; sulcus narrow and shallow. External surface of ventral valve ornamented with regular concentric lamellae, with a row of fine biramouse spine bases on anterior margin; numbering 4 lamellae in 5 mm, and 15–16 spine bases in 5 mm at about midlength of valve. Ventral interior with a median septum extending to one-third valve length and a pair of slightly divergent dental adminicula and covered with numerous fine radial grooves.

**Remarks.—**These specimens are referred to *Kitakamithyris tyoanjiensis* Minato (1951, p. 374, pl. 1, fig. 3; pl. 4, fig. 7), from the upper part of the Choanji Formation (upper Famennian) of Choanji, South Kitakami Belt, in having small and closely arranged spine bases on the ventral valve. *Kitakamithyris hikoroitiensis* Minato (1951, p. 375, pl. 1, fig. 1), from the upper part of the Choanji Formation of Choanji, is readily distinguished from *K. thoanjiensis* in having wider-spaced and larger spine bases on the ventral valve.

**Occurrence.—**HK1 Unit.

**Distribution.—**Upper Devonian (upper Famennian)–upper Tournaisian: northeastern Japan (Choanji and Hikoroichi in the South Kitakami Belt).

*Kitakamithyris hikoroitiensis* Minato, 1951
(Figs. 20B, C, 21B, 29A, B)

*Torynifer* (*Kitakamithyris*) *hikoroitiensis* Minato, 1951, p. 375, pl. 1, fig. 1.
*Kitakamithyris hikoroitiensis* Minato, 1952, p. 171, pl. 7, fig. 3; pl. 8, fig. 6; Minato et al., 1979a, pl. 16, fig. 1.
*Kitakamithyris semicircularis* 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 KF188 and KF201: (1) external and internal moulds of a conjoined shell, NU-B2084; (2) external and internal moulds of three ventral valves, NU-B2193–2195; and (3) internal mould of a ventral valve, NU-B2085.

**Description.—**Shell medium in size for genus, subelliptical in outline, with maximum width at midlength; length 31 mm, width about 29 mm in the largest specimen (NU-B2193). Ventral valve gently convex in lateral profile, most convex in umbonal region, nearly flat in anterior portion; sulcus narrow and very shallow. Dorsal valve gently convex in both lateral and anterior profiles, without fold. External surface of both valves ornamented with regular concentric lamellae bearing a row of biramous spine bases; numbering 2 lamellae in 5 mm and 4–5 spine bases in 5 mm at about midlength of ventral valve. Ventral interior with a long median septum and a pair of divergent dental adminicula. Dorsal interior not well preserved. Inner surfaces of both valves sculptured with fine radiating grooves.

**Remarks.—**These specimens are referred to *Kitakamithyris hikoroitiensis* Minato (1951, p. 375, pl. 1, fig. 1), from the upper part of the Choanji Formation at Choanji, in size, shape and external ornament of the shell, particularly in having rather large and sporadically arranged spine bases on the both ventral and dorsal valves. *Kitakamithyris semicircularis* Minato (1952, p. 171, pl. 7, fig. 6; pl. 8, fig. 5; pl. 10, fig. 3), from the Choanji and Arisu Formations of the South Kitakami Belt, is deemed a junior synonym of *K. hikoroitiensis*. The type species, *Kitakamithyris tyoanjiensis* Minato, 1951, is readily distinguished from the present species by the smaller and more closely arranged spine bases on the both valves.

**Occurrence.—**HK1 and HK2 units.

**Distribution.—**Upper Devonian (upper Famennian)–lower Visean: northeastern Japan (Choanji, Hikoroichi and Yokota in the South Kitakami Belt).

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

**Type species.—***Torynifer criticus* Hall and Clarke, 1894.

*Torynifer asiatica* Besnossova in Besnossova et al., 1962
(Fig. 32A, B)

*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* Besnossova in Besnossova et

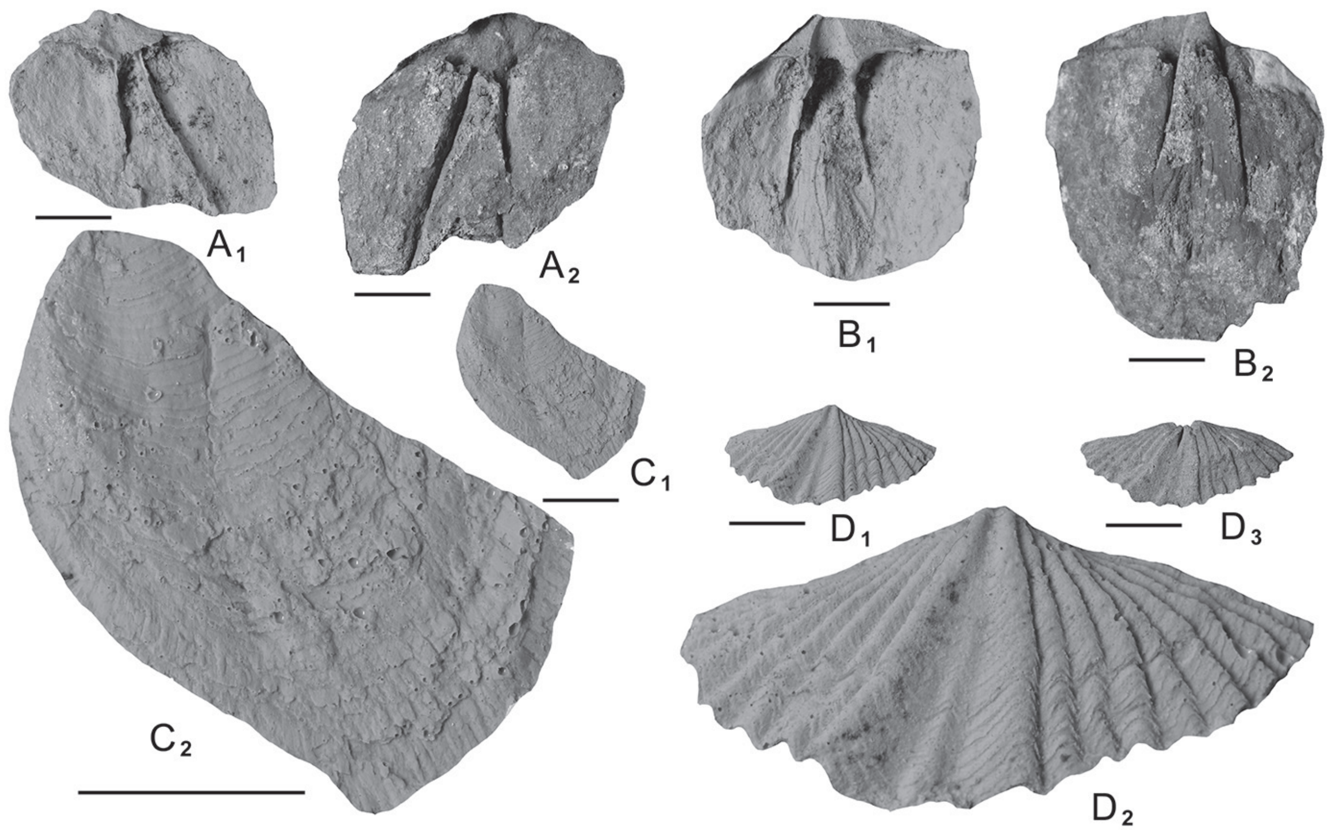


FIGURE 33. Brachiopods of the HK4 assemblage (4). **A, B,** *Dimegelasma* sp., A, internal latex cast ($A_1$) and internal mould ($A_2$) of ventral valve, IGPS97911; B, internal latex cast ($B_1$) and internal mould ($B_2$) of ventral valve, IGPS97910; **C,** *Cleiothyridina* sp., external latex cast ($C_1$, $C_2$) of valve (ventral or dorsal uncertain), IGPS97907; **D,** *Punctospirifer iwatensis* sp. nov., external latex cast ($D_1$, $D_2$) and internal mould ($D_3$) of ventral valve, NU-B2231 (holotype). Scale bars represent 1 cm.

al., 1962, p. 176, pl. C-23, figs. 4–5; Besnossova 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 et al., 1969, p. 270, pl. 66, figs. 7, 8.

*Torynifer asiatica* Besnossova. Pavlova, 1969, p. 63, pl. 4, figs. 1–6; pl. 11, figs. 6, 7; pl. 13, fig. 3; text-figs. 37–39.

**Material.**—Three specimens from locality KAC1: (1) external and internal moulds of a conjoined shell, NU-B2228; and (2) external and internal moulds of two ventral valves, NU-B2229, 2230.

**Description.**—Shell large in size for genus, transversely subelliptical in outline, with greatest width at about two-thirds length; cardinal extremities rounded; anterior commissure slightly uniplicate; length 34 mm, width 50 mm in the largest specimen (NU-B2228). Ventral valve gently and unevenly convex in lateral profile, most convex in umbonal region; sulcus shallow but distinct in anterior half of valve. Dorsal valve gently convex in lateral profile; fold very low near anterior margin of valve. External surface of ventral valve ornamented with slightly irregular concentric lamellae bearing a row of fine biramous spine bases on anterior margin; numbering 2 lamellae in 5 mm at just anterior to umbo, 4 lamellae in 5 mm at midlength, and 5 lamellae in 5 mm near anterior valve margin; spine bases regularly arranged on front of each lamella with a density of 7 in 5 mm at about midlength. External ornament of dorsal valve similar to opposite valve. Ventral interior with a median septum extending to one third valve length and a pair of strong dental adminicula. Dorsal vave interior with a long thin median septum extending to half length of valve; other internal structures not well preserved. Internal surfaces of both valves sculptured with numerous fine radial grooves.

**Remarks.**—These specimens are referred to *Torynifer asiatica* Besnossova in Besnossova et al. (1962, p. 176, pl. C-23, figs. 4–5), from the lower Tersinsk Horizon (upper Tournaisian) of the Kuznetsk Basin, on account of the large, gently biconvex shell, with shallow ventral sulcus and low dorsal fold. *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 and dorsal fold.

**Occurrence.**—HK4 Unit.

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

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 sibirica* Sokolskaya in Sarytcheva et al., 1963
(Fig. 20F–H)

*Syringothyris sibirica* Sokolskaya in Sarytcheva et al., 1963, p. 277, pl. 49, figs. 1–10.

**Material.**—Four specimens from localities KAC3 and KF201: (1) internal mould of two ventral valves, NU-B2197, 2198; and (2) external and internal moulds of two dorsal valves, NU-B2199, 2200.

**Description.**—Shell medium in size for genus, transversely subsemicircular in outline, with greatest width at hinge; length about 35 mm, width more than 70 mm in the largest dorsal valve specimen (NU-B2199). Ventral valve having a high, slightly concave interarea (height about 24 mm in the larger ventral valve, NU-B2198). Dorsal valve gently convex in lateral profile; fold wide and low. External surface of dorsal valve ornamented with simple rounded costae on flanks, but smooth on fold; numbering 5–6 costae in 10 mm at about midlength. Internally, ventral valve having a syrinx and a pair of strong divergent dental adminicura.

**Remarks.**—These specimens are fragmentarily preserved, but can be referred to *Syringothyris sibirica* Sokolskaya (in Sarytcheva et al., 1963, p. 277, pl. 49, figs. 1–10) from the upper Tournaisian–lower Visean of the Kuznetsk Basin, central Russia, by the rather low ventral interarea and wide, low dorsal fold. *Syringothyris transversa* Minato (1951, p. 377, pl. 5, fig. 1), from the Arisu Formation of the Shimoarisu area, South Kitakami Belt, differs from the present species in having a highly elevated fold in the dorsal valve.

**Occurrence.**—HK1 Unit.

**Distribution.**—Upper Tournarisian–lower Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt) and central Russia (Kuznetsk Basin).

Subfamily PERMASYRINXINAE Waterhouse, 1986
Genus *PSEUDOSYRINX* Weller, 1914

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

*Pseudosyrinx* cf. *missouriensis* Weller, 1914
(Fig. 28M, N)

cf. *Pseudosyrinx missouriensis* Weller, 1914, p. 406, pl. 65, figs. 5–9; pl. 66, figs. 11–13.

**Material.**—Two specimens from locality KF202: (1) external and internal moulds of a ventral interarea, NU-B2041; and (2) internal mould of a dorsal valve, NU-B2108.

**Remarks.**—The specimens from Hikoroichi are fragmentarily preserved, but they can be assigned to the genus *Pseudosyrinx* in possessing a high, triangular and flattened ventral interarea and in lacking syrinx. The Hikoroichi 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 the large size (length 40 mm, width about 72 mm in the dorsal valve, NU-B2108) and external ornament of numerous simple rounded costae on the ventral valve. However, accurate comparison is difficult for the poorly preserved specimens.

**Occurrence.**—HK2 Unit.

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

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

*Dimegelasma* sp.
(Fig. 33A, B)

*Dimegelasma* sp. Tazawa and Katayama, 1979, p. 171, pl. 11, figs. 15, 16.
*Tomiopsis* sp. Tazawa, 1984b, p. 308, pl. 61, fig. 10.

**Material.**—Two specimens from locality KF163, internal moulds of two ventral valves, IGPS97910, 97911.

**Remarks.**—These specimens were described by Tazawa (1984b, p. 308, pl. 61, fig. 10) as *Tomiopsis* sp. But the Hikoroichi species can be assigned to the genus *Dimegelasma* by the medium to large size (length about 46 mm, width about 39 mm in the larger specimen, IGPS97910), gently convex ventral valve, with rounded cardinal extremities and by the presence of very long thin dental plates in the ventral valve. *Dimegelasma* sp. Tazawa and Katayama (1979, p. 171, pl. 11, figs. 15–16), from the middle part of the Odaira Formation in the Yokota area, South Kitakami Belt, is deemed conspecific with the present species. The Hikoroichi 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.**—HK4 Unit.

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

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

*Punctospirifer plicatosulcatus* Glenister, 1955
(Fig. 29D)

*Punctospirifer plicatosulcatus* Glenister, 1955, p. 69, pl. 6, figs. 26–29; pl. 8, figs. 10–12; Roberts, 1971, p. 268, pl. 58, figs. 1–16; Thomas, 1971, p. 168, pl. 25, figs. 3–7, text-figs. 63, 64.

**Material.**—One specimen from locality KF202, external mould of a ventral valve, NU-B2106.

**Remarks.**—The single ventral valve specimen from Hikoroichi can be referred to *Punctospirifer plicatosulcatus* Glenister (1955, p. 69, pl. 6, figs. 26–29; pl. 8, figs. 10–12), from the Moogooree Limestone of the Carnarvon Basin, western Australia, in the small, transverse shell (length about 10 mm, width about 18 mm), a few strong costae with numerous closely-spaced concentric lamellae and in having a distinct median sulcal costa in the ventral valve. The most allied species, *Punctospirifer solidirostris* (White, 1860), redescribed by Carter (1972, p. 490, pl. 4, figs. 24–29) from the Gilmore City Limestone of north-central Iowa, differs from *P. plicatosulcatus* in the less transverse outline.

**Occurrence.**—HK2 Unit.

**Distribution.**—Lower Tournaisian–lower Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt), northwestern Australia (Bonaparte Gulf Basin and Canning Basin) and western Australia (Carnarvon Basin).

*Punctospirifer gigantiformis* Lee and Gu in Lee et al., 1980
(Fig. 29C)

*Punctospirifer gigantiformis* Lee and Gu in Lee et al., 1980, p. 420, pl. 157, figs. 4, 13, 15, 17; Gu, 1992, p. 252, pl. 66, figs. 10, 12; pl. 72, fig. 13; pl. 73, figs. 4–6, 8, 10, 20.

**Material.**—One specimen from locality KF202, external mould of a ventral valve, NU-B2107.

**Remarks.**—The single ventral valve specimen from Hikoroichi is referred to *Punctospirifer gigantiformis* Lee and Gu in Lee et al. (1980, p. 420, pl. 157, figs. 4, 13, 15, 17), from the Lujuantun Formation of Jilin, northeastern China, by the large size (length about 25 mm, width more than 30 mm) and in having deep sulcus with V-shaped bottom and subangular costae on lateral flanks. This species is distinguished from most species of the genus by the large size.

**Occurrence.**—HK2 Unit.

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

*Punctospirifer iwatensis* sp. nov.
(Fig. 33D)

**Etymology.**—Named after the fossil locality, Iwate Prefecture.

**Material.**—One specimen from locality KF148, external and internal moulds of a ventral valve, NU-B2231 (holotype).

**Diagnosis.**—Large, transverse *Punctospirifer*, with ventral sulcus bearing a median costa on anterior two-thirds and 9 simple subangular costae on each lateral slope of ventral valve.

**Description.**—Shell large in size for genus, transversely subelliptical in outline; cardinal extremities acute; length 13 mm, width 30 mm in the holotype (NU-B2231). Ventral valve moderately and unevenly convex in lateral profile, strongly convex at umbonal region, becoming gently convex anteriorly; interarea moderately high and slightly concave; delthyrium open, broad, measuring 5 mm wide at base; sulcus wide and deep, about 10 mm in width at anterior margin, and bearing a median costa on anterior two-thirds; lateral slopes gently convex and nearly flat in anterior profile. External ornament of ventral valve consisting of simple subangular costae and closely-spaced imbricate growth laminae; numbering 9 costae on each lateral slope, 5–6 laminae in 3 mm at about midlength. Internally, ventral valve having a pair of short, slightly divergent dental adminicula and a stout, short median septum.

**Remarks.**—*Punctospirifer iwatensis* sp. nov. resembles *Punctospirifer magnus* Poletaev (2000, p. 36, pl. 5, figs. 15–17), from the upper Tournaisian of the Donets Basin, western Russia, in size and outline, but differs from the Russian species in the smaller size and in having wider sulcus and fewer costae on the ventral valve. *Punctospirifer transversus* (McChesney, 1860), redescribed by Butts (2007, p. 60, figs. 5.54–5.58) from the Arco Hills Formation (Chesterian) of Idaho, differs from *P. iwatensis* in the smaller size and in having alate cardinal extremities. *Punctospirifer plicatosulcatus* Glenister (1955, p. 69, pl. 6, figs. 26–29; pl. 6, figs. 10–12), from the Moogooree Limestone of the Carnarvon Basin, western Australia, differs from the present species in the smaller size and in having fewer costae on the ventral lateral slopes.

**Occurrence.**—HK4 Unit.

*Punctospirifer* sp.
(Fig. 20D, E)

**Material.**—Two specimens from localities KF200 and KF201: (1) internal mould of a ventral valve, NU-B2207; and (2) internal mould of a dorsal valve, NU-B2208.

**Remarks.**—These specimens are safely assigned to the genus *Punctospirifer* by the small, transverse (length about 14 mm, width more than 22 mm in the larger specimen, NU-B2207) and punctate shell, ornamented with few strong costae and numerous closely-spaced concentric lamellae. However, specific identification is difficult for the poorly preserved material.

**Occurrence.**—HK1 Unit.

Order TEREBRATULIDA Waagen, 1883
Suborder TEREBRATULIDINA Waagen, 1883
Superfamily DIELASMATOIDEA Schuchert, 1913
Family BEECHERIIDAE Smirnova, 2004
Genus *BEECHERIA* Hall and Clarke, 1893

**Type species.**—*Beecheria davidsoni* Hall and Clarke, 1893.

*Beecheria khalfini* Besnossova in Sarytcheva et al., 1963
(Fig. 20I)

*Beecheria khalfini* Besnossova in Sarytcheva et al., 1963, p. 338, pl. 64, figs. 4–6; Zhang et al., 1983, p. 383, pl. 124, fig. 12.

**Material.**—One specimen from locality KF200, internal mould of a conjoined shell, NU-B2217.

**Description.**—Shell medium in size for genus, elongately suboval in outline, with rectimarginate anterior commissure and rounded front margin, widest at midlength; length 32 mm, width about 18 mm. Ventral valve gently convex in lateral profile, except for moderately convex umbonal region; umbo narrow, with small permesothyrid foramen. Dorsal valve gently convex; interior of valve with a pair of diverging hinge plates and a low median ridge.

**Remarks.**—This specimen can be referred to *Beecheria khalfini* Besnossova (in Sarytcheva et al., 1963, p. 338, pl. 64, figs. 4–6), from the lower Tournaisian–lower Visean of the Kuznetsk Basin, on account of size and shape of the shell, particularly in having rather strongly convex umbo in the ventral valve. *Beecheria chouteauensis* (Weller, 1914, p. 257, pl. 32, figs. 1–17), from the Chouteau and Pierson limestones of Missouri, differs from the present species in having more flattened shell and less convex ventral umbo.

**Occurrence.**—HK1 Unit.

**Distribution.**—Lower Tournaisian–lower Visean: northeastern Japan (Hikoroichi in the South Kitakami Belt) and central Russia (Kuznetsk Basin).

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

< 地名・地層名 >

| | |
|---|---|
| Arisu Formation | 有住層 |
| Choanji | 長安寺 |
| Higuchizawa | 樋口沢 |
| Hikami Granite | 氷上花崗岩 |
| Hikoroichi Formation | 日頃市層 |
| Hina | 日南 |
| Kanenokura Stage | 金ノ倉階 |
| Karaumedate Formation | 唐梅館層 |
| Karoyama Formation | 加労山層 |
| Kawauchi Formation | 川内層 |
| Mt. Goyosan | 五葉山 |
| Nagaiwa Formation | 長岩層 |
| Nagasaka | 長坂 |
| Nakazato Formation | 中里層 |
| Nisawa | 荷沢 |
| Odaira Formation | 大平層 |
| Ofunato | 大船渡 |
| Okuhinotsuchi | 奥火の土 |
| Omori | 大森 |
| Onimaru Formation | 鬼丸層 |
| Otsubo | 小坪 |
| Sakamotozawa | 坂本沢 |
| Shimoarisu | 下有住 |
| Shizu | 清水 |
| Soma | 相馬 |
| Yokota | 横田 |

## APPENDIX

Topographic and stratigraphic locations, lithologies and containing brachiopod species of the 16 fossil localities (KAC1, KAC3, KF148, KF151, KF152, KF153, KF156, KF163, KF167, KF171, KF172, KF174, KF188, KF200, KF201 and KF202) in the Hikoroichi area.

KAC1: Upper stream of small valley at SE of Onimaru (39° 06′ 57″ N, 141° 39′ 07″ E), dark grey fine-grained sandstone of the upper part of the HK4 Unit, with *Leptagonia analoga*, *Argentiproductus margaritaceus*, *Ovatia* cf. *prolata*, *Schizophoria resupinata* and *Torynifer asiatica*.

KAC3: NE of Omori (39° 06′ 37″ N, 141° 39′ 38″ E), dark grey fine-grained sandstone of the lower part of the HK1 Unit, with *Marginatia magna*, *Tylothyris laminosa* and *Syringothyris sibirica*.

KF148: Near (60 m SW) the summit of Mt. Senokidayama (39° 06′ 49″ N, 141° 39′ 19″ E), medium-grained tuffaceous sandstone of the upper part of the HK4 Unit, with *Punctospirifer iwatensis*.

KF151: Northern ridge of Mt. Senokidayama, at 590 m N of the summit (39° 07′ 10″ N, 141° 39′ 17″ E), grey, fine-grained, calcareous sandstone of the top of the HK4 Unit, with *Spirifer liangchowensis*.

KF152: Northern ridge of Mt. Senokidayama, at 15 m SW of KF151 (39° 07′ 09″ N, 141° 39′ 16″ E), grey fine-grained sandstone of near the top of the HK4 Unit, with *Pustula pustulosa*.

KF153: Northern ridge of Mt. Senokidayama, at 20 m SW of KF151 (39° 07′ 08″ N, 141° 39′ 17″ E), grey, fine-grained, calcareous sandstone of the top of the HK4 Unit, with *Angiospirifer bisulcatus*.

KF156: Road cut at 150 m SW of junction of the Sakamotozawa and Onimarusawa valleys (39° 07′ 43″ N, 141° 39′ 26″ E), greenish-grey, fine-grained tuffaceous sandstone of near the base of the HK4 Unit, with *Rotaia hikoroichiensis*.

KF163: Upper Higuchizawa Valley (39° 07′ 09″ N, 141° 39′ 22″ E), grey, arenaceous limestone of the upper part of the HK4 Unit, with *Rhipidomella michelini* and *Dimegelasma* sp.

KF167: Eastern slope facing the Onimarusawa Valley, 280 m SW of junction of the Sakamotozawa and Onimarusawa valleys (39° 07′ 43″ N, 141° 39′ 19″ E), grey, fine-grained sandstone of the lower part of the HK4 Unit, with *Karavankina jizodoensis*, *Orthotetes keokuk*, *Schizophoria resupinata* and *Cleiothyridina* sp.

KF171: Hill along the eastern side of the Onimarusawa Valley (39° 07′ 26″ N, 141° 39′ 22″ E), black shale of near the base of the HK2 Unit, with *Marginatia burlingtonensis*.

KF172: Hill along the eastern side of the Onimarusawa Valley (39° 07′ 27″ N, 141° 39′ 18″ E), black shale of the lower part of the HK2 Unit, with *Leptagonia analoga* and *Marginatia burlingtonensis*.

KF174: Hill along the eastern side of the Onimarusawa Valley (39° 07′ 34″ N, 141° 39′ 29″), black shale of the upper part of the HK2 Unit, with *Marginatia burlingtonensis*.

KF188: Hill along the eastern side of the Onimarusawa Valley (39° 07′ 35″ N, 141° 39′ 31″ E), black shale of the upper part of the HK2 Unit, with *Marginatia burlingtonensis*, *Ovatia laevicosta*, *Schizophoria resupinata* and *Kitakamithyris hikoroichiensis*.

KF200: Southern upper stream of the Higuchizawa Valley (39° 06′ 43″ N, 141° 39′ 35″ E), grey fine-grained sandstone of the lower part of the HK1 Unit, with *Schizophoria resupinata*, *Cleiothyridina harkeri*, *Kitakamithyris tyoanjiensis*, *Punctospirifer* sp. and *Beecheria khalfini*.

KF201: Eastern slope at 120 m NE of KF200 (39° 6′ 47″ N, 141° 39′ 39″ E), grey fine-grained sandstone of the lower part of the HK1 Unit, with *Leptagonia analoga*, *Plicochonetes* sp., *Tolmatchoffia robusta*, *Marginatia burlingtonensis*, *M. magna*, *Ovatia* sp., *Schizophoris resupinata*, *Rhynchopora* sp., *Unispirifer mediocris*, *Acuminothyris keokuk*, *Brachythyris suborbicularis*, *Kitakamithyris tyoanjiensis*, *K. hikoroitiensis*, *Syringothyris sibirica* and *Punctospirifer* sp.

KF202: Onimaru quarry, NE of Onimaru (39° 07′ 28″ N, 141° 39′ 20″ E), dark grey, fine-grained calcareous sandstone of the upper part of the HK2 Unit, with *Leptagonia analoga*, *Rugosochonetes* cf. *hardrensis*, *Leiochonetes onimarensis*, *Tolmatchoffia robusta*, *Marginatia burlingtonensis*, *Echinoconchus punctatus*, *Ovatia laevicosta*, *Linoprotonia ashfellensis*, *L. hikoroichiensis*, *Gigantoproductus crassiventer*, *G. latiexpansus*, *Orthotetes keokuk*, *Rhipidomella michelini*, *Rotaia hikoroichiensis*, *Actinoconchus expansus*, *A. paradoxus*, *Lamellosathyris qaidamensis*, *Hustedia* sp., *Spirifer karagai*, *Unispirifer striatoconvolutus*, *U. kozuboensis*, *Tegulocrea incerta*, *Acuminothyris triangularis*, *Pseudosyrinx* cf. *missouriensis*, *Punctospirifer plicatosulcatus,* and *P. gigantiformis.*