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ARTICLE

EARLY PERMIAN (CISURALIAN) BRACHIOPODS FROM NAGAIWA–SAKAMOTOZAWA, SOUTH KITAKAMI BELT, JAPAN

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ABSTRACT

This study describes 44 species of early Permian (Cisuralian) brachiopods in 37 genera (including two new species, *Jakutoproductus japonicus* sp. nov. and *Anemonaria kitakamiense* sp. nov.) from the Sakamotozawa and Kanokura Formations in the Nagaiwa–Sakamotozawa area, eastern part of the South Kitakami Belt (southern Kitakami Mountains), northeastern Japan. Based mainly on brachiopod biostratigraphy, the lower part (SK1 Unit) of the Sakamotozawa Formation is correlated with the Sakmarian, the upper part (SK4 Unit) of the Sakamotozawa Formation with the lower Kungurian, and the lower part (KN1 Unit) of the Kanokura Formation with the upper Kungurian. In terms of palaeobiogeography, the Sakmarian fauna (the SK1 assemblage from the SK1 Unit) is a mixed Boreal–Tethyan fauna with a predominance of Boreal elements, and has a close affinity with the faunas of central Russia (southern Urals), northern Russia (Timan and northern Urals) and northern China (Inner Mongolia). The Kungurian fauna (the SK4 assemblage from the SK4 Unit and the KN1 assemblage from the KN1 Unit) is a mixed Boreal–Tethyan–Panthalassan fauna, and is similar to the faunas of northwestern (Xinjiang) to northeastern (Jilin) China. Thus, the South Kitakami region belonged to a transitional zone (the Northern Transitional Zone) between the Boreal and Tethyan realms in the Northern Hemisphere. This region was probably a shallow sea bordering a microcontinent (the Proto-Japan Block) that was located near and to the east of the North China Block at the eastern end of the Central Asian Orogenic Belt during the Sakmarian–Kungurian.

Key words: Brachiopoda, early Permian, Japan, Nagaiwa–Sakamotozawa, South Kitakami Belt

田沢純一・新谷友彦 (2022) 南部北上帯長岩–坂本沢地域から産出する前期ペルム紀（南ウラル世）腕足類．福井県立恐竜博物館紀要 21：1–58.

南部北上帯長岩–坂本沢地域に分布する坂本沢層の下部（SK1 ユニット）と上部（SK4 ユニット）および叶倉層下部（KN1 ユニット）から産出する 37 属 44 種（2 新種，*Jakutoproductus japonicus* sp. nov., *Anemonaria kitakamiense* sp. nov. を含む）の前期ペルム紀（南ウラル世）腕足類を記載した．主にこれらの腕足類により，坂本沢層は Sakmarian 〜 Kungurian 下部に，また，叶倉層下部は Kungurian 上部に対比される．古生物地理学的に，Sakmarian のフォーナ（SK1 ユニットから産出する SK1 群集）は ボレアル型優勢のボレアル型–テチス型混合フォーナで，ロシア中央部（ウラル山脈南部），ロシア北部（チマン，ウラル山脈北部），中国北部（内蒙古）のフォーナに類似する．Kungurian のフォーナ（SK4 ユニットから産出する SK4 群集および KN1 ユニットから産出する KN1 群集）はボレアル型–テチス型–パンサラッサ型混合フォーナで，中国西北部（新疆）〜中国東北部（吉林）のフォーナに類似する．南部北上地域は，前期ペルム紀（Sakmarian–Kungurian）に北半球のボレアル区とテチス区境界付近にあった北漸移帯に属し，おそらく中央アジア造山帯の東端，北中国地塊の東方にマイクロコンチネントとして存在した原日本地塊（新称）の縁辺浅海域であったと推定される．

INTRODUCTION

Permian marine sedimentary rocks are widely distributed in the South Kitakami Belt, northeastern Japan. The Nagaiwa–Sakamotozawa area (i.e., Nagaiwa and Sakamotozawa, Hikoroichi-cho, Ofunato City, Iwate Prefecture; Figs. 1–4) in the eastern part of the belt is the type locality of the lower Permian (Cisuralian) Sakamotozawa Formation (named by Onuki, 1937). In this area, the stratigraphy of the Sakamotozawa Formation has been studied by Onuki (1937, 1956, 1969), Yamada (1959), Mikami (1965), Kanmera and Mikami (1965a, 1965b), Minato et al. (1979b) and Shintani (2009, 2011). Recently, Ueno et al. (2007, 2009) described fusulines from the lower and upper parts of the Sakamotozawa Formation, and Tazawa and Shintani (2010, 2015) and Shintani (2011)

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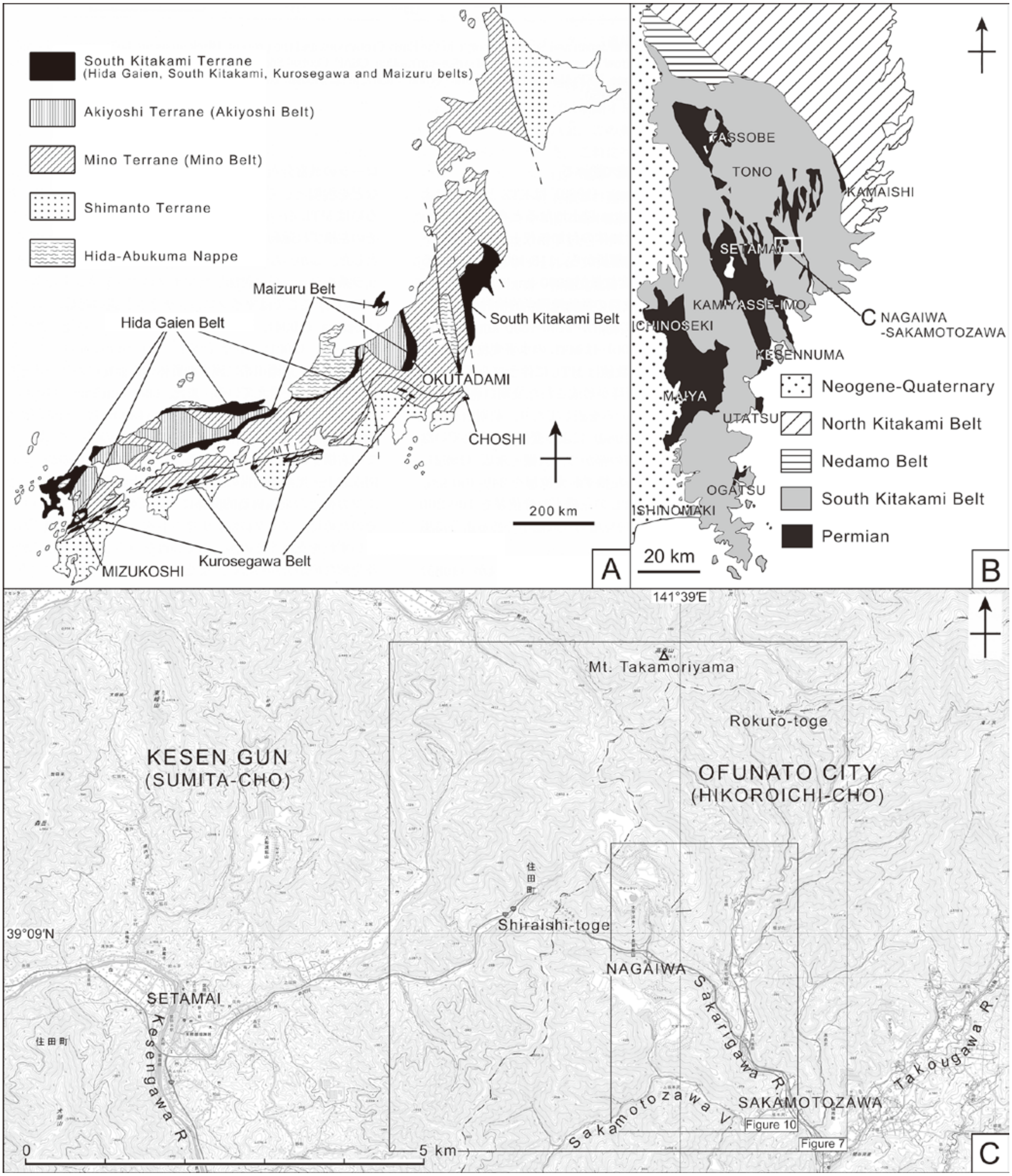

FIGURE 1. Maps showing the location and geology of the Nagaiwa–Sakamotozawa area, South Kitakami Belt. **A**, Geotectonic map of the Japanese Islands, showing the distribution of the South Kitakami Belt (based on Tazawa, 2018); **B**, geotectonic map of the northeastern Honshu, Japan, showing the distribution of the Permian rocks in the South Kitakami Belt (based on Kawamura et al., 2013); **C**, topographical map of the Nagaiwa–Sakamotozawa area and the surroundings. Enclosures are corresponding to Figs. 7 and 10 (using the electronic topographical map of GSI).

FIGURE 2. A view of the central to northern Nagaiwa–Sakamotozawa area, showing two Permian limestone quarries, the Sakamotozawa Quarry and the Nagaiwa Quarry.

described brachiopods from the same horizons. However, little is known about the stratigraphy, fossil content and age of the overlying Kanokura Formation (named by Onuki, 1937). Mikami (1965) and Kanmera and Mikami (1965a) studied the stratigraphy of the Kanokura Formation but did not report any fossils; therefore, the age of the Kanokura Formatrion in the Nagaiwa–Sakamotozawa area has remained uncertain.

In the present study, we describe brachiopods from the lower and upper parts of the Sakamotozawa Formation and from the lower part of the Kanokura Formation in the Nagaiwa–Sakamotozawa area and discuss the age and palaeobiogeography of the brachiopod faunas. Most of the brachiopod specimens described herein were collected by T. Shintani in 2006–2009 during the course of undergraduate and graduate studies at the Niigata University under the supervision of J. Tazawa. The specimens are now registered and housed in the Faculty of Science, Niigata University, Niigata, Japan (prefix NU-B, numbers 1212–1286, 1826–1830, 1867–1900. 2280–2286, 2301 and 2302).

PREVIOUS WORK

Stratigraphy

Previous studies on the stratigraphy of the lower Permian rocks corresponding to the Sakamotozawa Formation in the Nagaiwa–Sakamotozawa area are summarized in Fig. 5. In the early studies, Endo (1924) and Onuki (1937) named the limestone-dominated formation the “Fusulina Limestone” and the Sakamotozawa Stage, respectively. Modern stratigraphical studies on the Permian of the Nagaiwa–Sakamotozawa area began in 1950s after Minato et al. (1954) established the Permian stratigraphy in Setamai, 6 km west of Nagaiwa–Sakamotozawa. Onuki (1956) proposed three members in the Sakamotozawa Formation, namely, the Yubanosawa Slate Member, the Shiratorizawa Limestone Member and the Motoiwazawa Sandstone Member in ascending stratigraphic order. However, the ages of the members were uncertain due to a paucity of palaeontological data. Mikami (1965) and Kanmera and Mikami (1965a, 1965b) established an

FIGURE 3. A distant view (**A**) and a close view (**B**) of the fossil localities SSK27 and SSK28 in the upper stream of the Imahorazawa Valley, northern Nagaiwa–Sakamotozawa area.

FIGURE 4. A view of outcrop of sandstone of the KN1 Unit, lower Kanokura Formation in the fossil locality SSK17, 630 m SE of Nagaiwa, central part of the Nagaiwa–Sakamotozawa area.

excellent fusulinid biostratigraphy of the Sakamotozawa Formation in the Nagaiwa–Sakamotozawa area. According to those studies, the Sakamotozawa Formation is upper Wolfcampian–lower Leonardian in age, and is divided into two subformations and four members: the Lower Subformation (containing the Sa and Sb members) and the Upper Subformation (containing the Sc and Sd members). The boundary between the two subformations is an angular unconformity. Recently, Shintani (2009, 2011) proposed four members (the Yubanosawa Sandstone Member, the Tashiroyama Limestone Member, the Shiratorizawa Limestone Member and the Shiraishi Sandstone-Limestone Member in ascending stratigraphic order) in the Sakamotozawa Formation. However, the names of the members are nomina nuda, because the proposal lacked designations and descriptions of the type localities of the members.

Palaeontology

Many taxonomic studies on the early Permian biota of the Sakamotozawa Formation in the Nagaiwa–Sakamotozawa area have been published: fusulines (Hanzawa, 1938, 1939; Igo, 1964; Kanmera and Mikami, 1965b; Ueno et al., 2007, 2009), corals (Minato, 1955; Minato and Kato, 1965a, 1965b), brachiopods (Tazawa and Shintani, 2010, 2015; Shintani, 2011) and calcareous algae (Endo, 1951, 1952). Fusulines and brachiopods are abundant in the studied area. Tazawa and Shintani (2010, 2015) and Shintani (2011) described 17 brachiopod species (in 14 genera) from the lower part of the Sakamotozawa Formation: *Echinauris opuntia* (Waagen), *Reticulatia* cf. *donetziana* (Licharew), *Echinaria* sp., *Juresania* sp., *Waagenoconcha humboldti* (d'Orbigny), *Edriosteges* cf. *multispinosus* Muir-Wood and Cooper, *Scacchinella* sp., *Linoproductus simensis* (Tschernyschew), *Auriculispina kanmerai* Tazawa and Shintani, *Terrakea* sp., *Cyclacantharia* sp., *Derbyia crassa* (Meek and Hayden), *D. dorsosulcata* Liu and Waterhouse, *D. sakamotozawensis* Shintani, *Meekella striaticostata* (Cox) and *M. nagaiwensis* Shintani and

<table>
<tr><th></th><th>Endo (1924)</th><th>Onuki (1937)</th><th colspan="2">Onuki (1956)</th><th colspan="3">Kanmera and Mikami (1965a)</th><th colspan="3">Minato et al. (1979b)</th><th colspan="2">Shintani (2009, 2011)</th><th colspan="3">Tazawa and Shintani (This study)</th></tr>
<tr><td rowspan="4">Lower Permian (Cisuralian)</td><td rowspan="4">"Fusulina Limestone"</td><td rowspan="4">Sakamotozawa Stage</td><td rowspan="4">Sakamotozawa Formation</td><td>Motoiwazawa Sandstone Member</td><td rowspan="4">Sakamotozawa Formation</td><td rowspan="2">Upper Subformation</td><td>Sd</td><td rowspan="4">Sakamotozawa Series</td><td rowspan="2">Kabayama Stage</td><td>PIe</td><td rowspan="4">Sakamotozawa Formation</td><td>Shiraishi Sandstone-Limestone M.</td><td rowspan="4">Sakamotozawa Formation</td><td>Upper</td><td>SK4</td></tr>
<tr><td rowspan="2">Shiratorizawa Limestone Member</td><td>Sc</td><td>PIc, PId</td><td>Shiratorizawa Limestone Member</td><td rowspan="2">Middle</td><td>SK3</td></tr>
<tr><td rowspan="2">Lower Subformation</td><td>Sb</td><td rowspan="2">Kawaguti Stage</td><td>PIb</td><td>Tashiroyama Limestone Member</td><td>SK2</td></tr>
<tr><td>Yubanosawa Slate Member</td><td>Sa</td><td>PIa</td><td>Yubanosawa Sandstone Member</td><td>Lower</td><td>SK1</td></tr>
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FIGURE 5. Comparison of stratigraphic schemes proposed for the lower Permian (Cisuralian) Sakamotozawa Formation in the Nagaiwa–Sakamotozawa area, South Kitakami Belt.

Rhynchopora sp.

In terms of biostratigraphy, Kanmera and Mikami (1965a, 1965b) proposed five fusuline zones in the Sakamotozawa Formation: the *Zellia nunosei* Zone and the *Nipponitella explicata–Monodiexodina langsonensis* Zone in the Lower Subformation, and the *Pseudofusulina vulgaris*, *Pseudofusulina fusiformis* and the *Pseudofusulina ambigua* zones in the Upper Subformation. They concluded that the Sakamotozawa Formation can be correlated with the upper Wolfcampian–lower Leonardian of California and Texas, the USA. Subsequently, Ueno et al. (2007, 2009) concluded that the Sakamotozawa Formation can be assigned to the Sakmarian–Bolorian based on fusulines from both the basal and the uppermost parts of the formation in the type area.

In terms of palaeobiogeography, Tazawa and Shintani (2010, 2015) proposed that the Sakamotozawa brachiopod fauna from the lower part of the Sakamotozawa Formation was a mixed Boreal–Tethyan fauna with a predominance of Boreal elements. This faunal affinity suggested that the South Kitakami region was probably part of the continental shelf bordering the eastern margin of the North China Block during the early Permian (Sakmarian).

STRATIGRAPHY

Permian rocks are exposed in the Nagaiwa–Sakamotozawa area, and they form the core and eastern wing of a syncline with an axis trending N–S to NNW–SSE and plunging gently to the south (Fig. 6). The Permian strata are divided into three formations: the lower limestone-dominated Sakamotozawa Formation; the middle sandstone-dominated Kanokura Formation; and the upper shale and conglomerate-dominated Toyoma Formation (named by Mabuti and Noda, 1934). In the Nagaiwa–Sakamotozawa area, brachiopod fossils occur in both the Sakamotozawa and Kanokura Formations. In this paper we

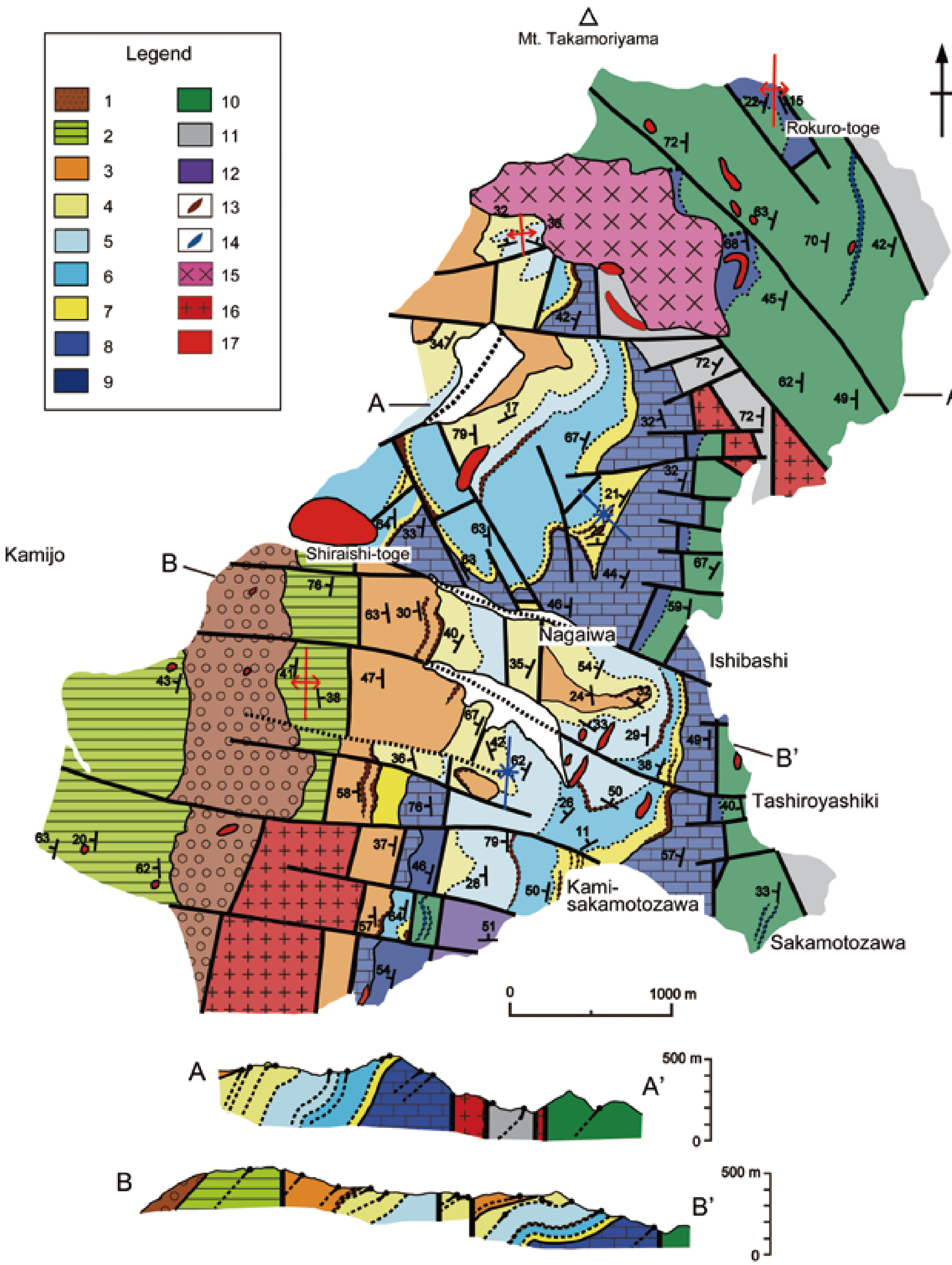

FIGURE 6. Geologic map of the Nagaiwa–Sakamotozawa area, Legend 1, 2, upper Permian Toyoma Formation (1, Usuginu-type conglomerate; 2, shale), 3, lower Permian Kanokura Formation (KN1 Unit); 4–7, lower Permian Sakamotozawa Formation (4, SK4 Unit; 5, SK3 Unit; 6, SK2 Unit; 7, SK1 Unit), 8, upper Carboniferous Nagaiwa Formation; 9, lower Carboniferous Onimaru Formation; 10, lower Carboniferous Hikoroichi Formation; 11, middle Devonian Nakazato Formation; 12, lower Devonian Ono Formation; 13, conglomerate; 14, limestone; 15, Cretaceous granite; 16, Hikami Granite; 17, dyke rock.

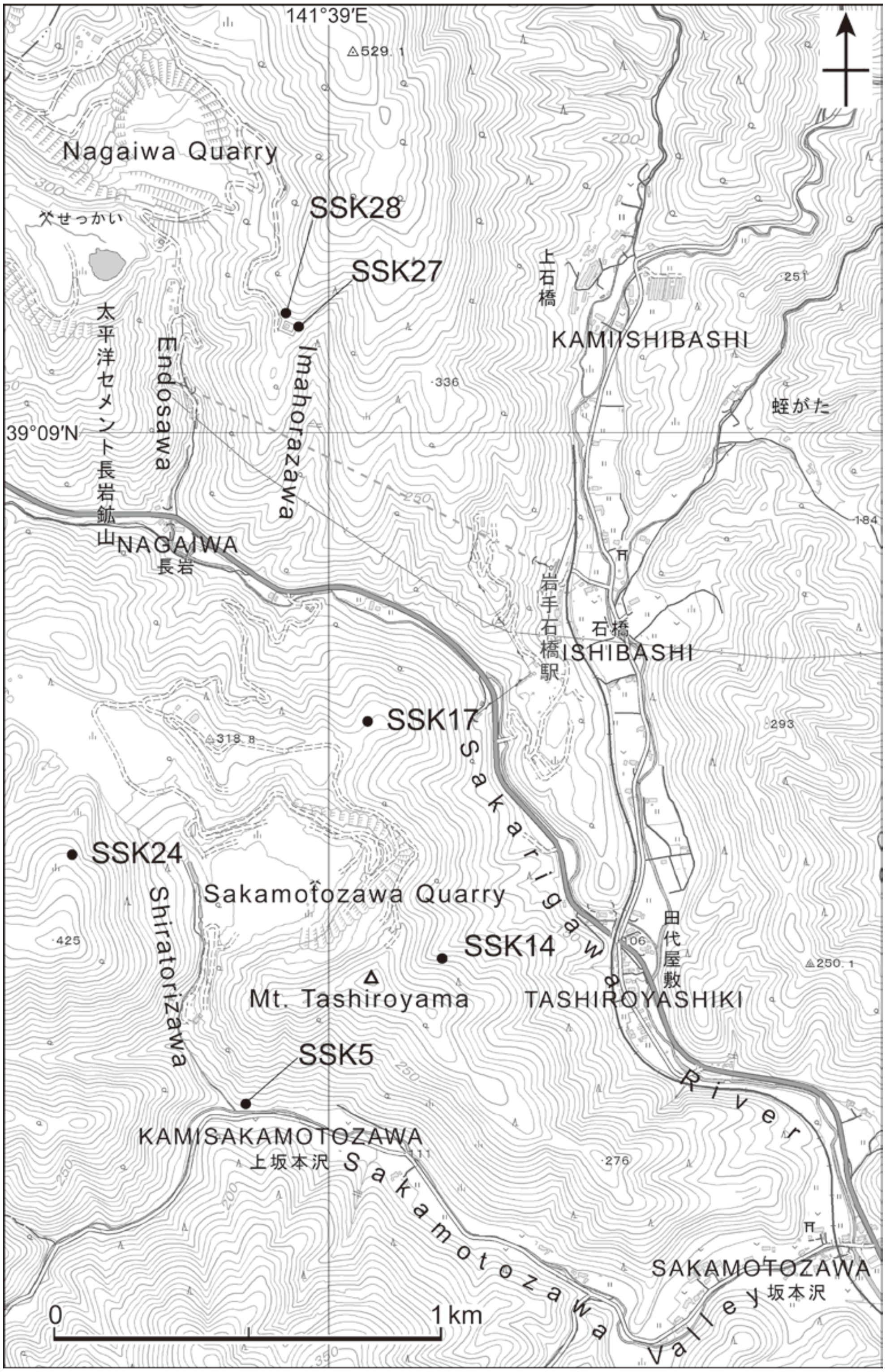

FIGURE 7. Map showing the fossil localities SSK5, SSK14, SSK17, SSK24, SSK27 and SSK28 (using the electronic topographical map of GSI).

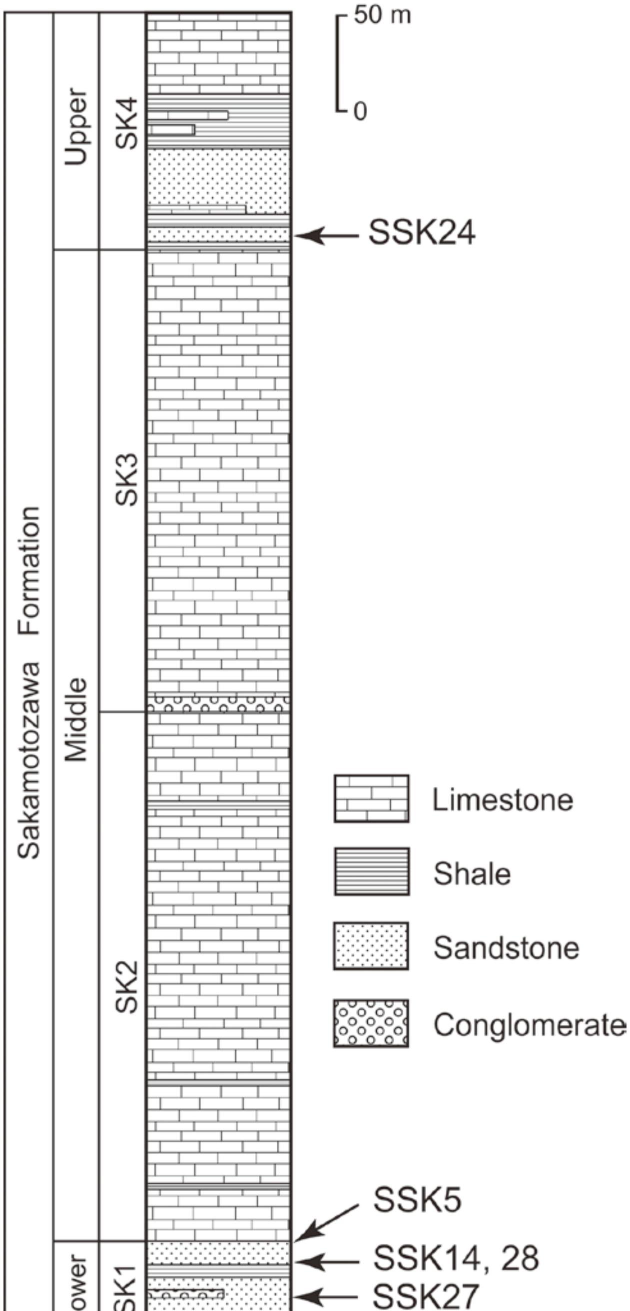

FIGURE 8. Generalized columnar section of the Sakamotozawa Formation in the Nagaiwa–Sakamotozawa area, South Kitakami Belt, showing the fossil horizons SSK27, SSK14, SSK28, SSK5 and SSK24.

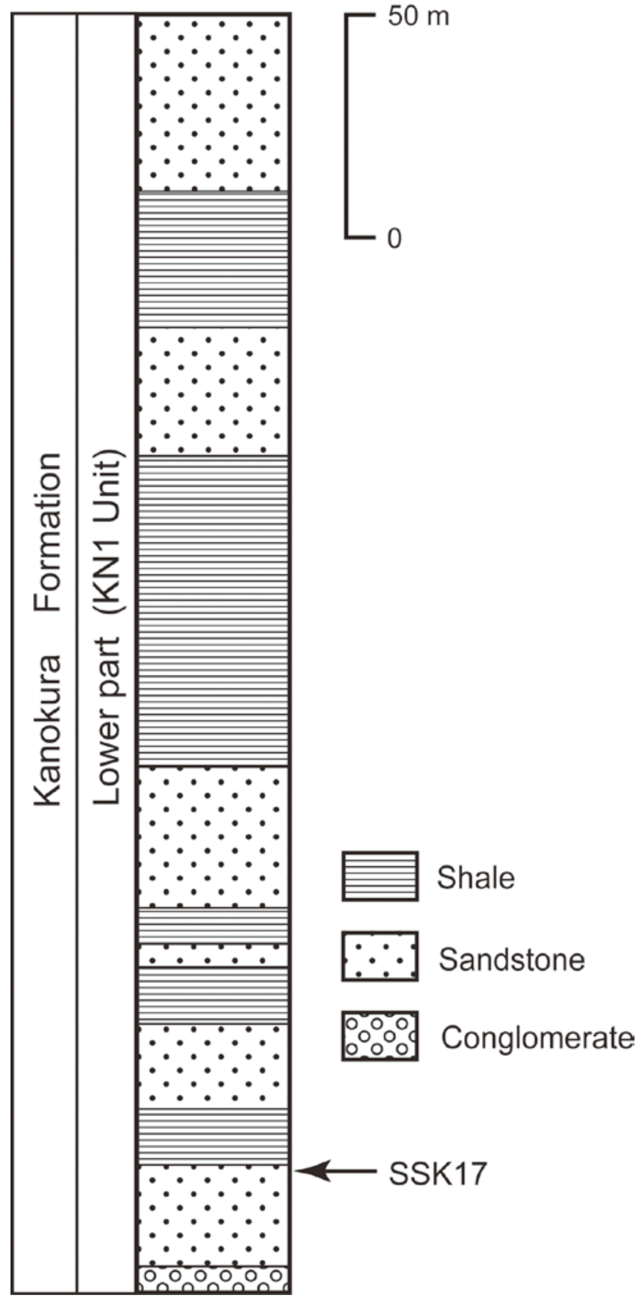

FIGURE 9. Generalized columnar section of the Kanokura Formation (Lower part. KN1 Unit) in the Nagaiwa–Sakamotozawa area, South Kitakami Belt, showing the fossil horizon SSK17.

divide the Sakamotozawa Formation into three parts (lower, middle and upper) and four lithostratigraphic units (the SK1, SK2, SK3 and SK4 units) and erect one unit (the KN1 Unit) in the Kanokura Formation.

Sakamotozawa Formation

The Sakamotozawa Formation in the Nagaiwa–Sakamotozawa area has a total thickness of 685 m and is subdivided into a lower part (the SK1 Unit: sandstone with thin layers of conglomerate and shale, 45 m thick), a middle part (the SK2 Unit: limestone with thin layers of shale, 280 m thick; and the SK3 Unit: limestone with a conglomerate bed at the base, 240 m

Species \ Formation, lithological unit and locality	Sakamotozawa F.					Kanokura F.
	SK1 Unit				SK4 U.	KN1 U.
	SSK27	SSK14	SSK28	SSK5	SSK24	SSK17
Rugaria semicircularis	A					
Jakutoproductus japonicus sp. nov.	A					
Transennatia insculpta						A
Anemonaria kitakamiense sp. nov.	R				A	
Echinauris opuntia	R					
Echinauris sp.						A
Reticulatia cf. *donetziana*	R					
Echinaria sp.	R					
Juresania sp.	R					
Waagenoconcha humboldti	A					
Edriosteges cf. *multispinosus*			R			
Xenosteges adherens					R	
Scacchinella sp.	R					
Linoproductus simensis	A					
Costatumurus pseudotruncata					R	
Anidanthus sp.						R
Auriculispina kanmerai	A				R	
Terrakea sp.		C	R			
Cyclacantharia sp.		R				
Pseudoleptodus sp.						R
Dicystoconcha lapparenti						R
Derbyia crassa		A	A			
D. dorsosulcata		A	C			
D. sakamotozawensis		A				
Meekella striatocostata	C	R	R			
M. depressa	C					
M. nagaiwensis	C	R	R			
Schuchertella cooperi	R					
Schuchertella sp.	R					
Streptorhynchus sibiricus		R				
Streptorhynchus sp.	R					
Stenoscisma sp.						R
Rhynchopora sp.			R	R		
Trasgu confinensis					C	
Pinegathyris royssiana		R				
Hustedia ratburiensis	A		R		R	R
Martinia lata						C
Jilinmartinia sp.						R
Martiniopsis sp.						R
Choristites sp.	A	R				
Phricodothyris asiatica	A					
Callispirina ornata	R		R			
Spiriferellina cristata	A	A	A			
Crenispirifer sagus					A	R

FIGURE 10. Occurrence of brachiopod species from the Sakamotozawa and Kanokura Formations in the Nagaiwa–Sakamotozawa area, South Kitakami Belt. A: abundant, C: common, R: rare.

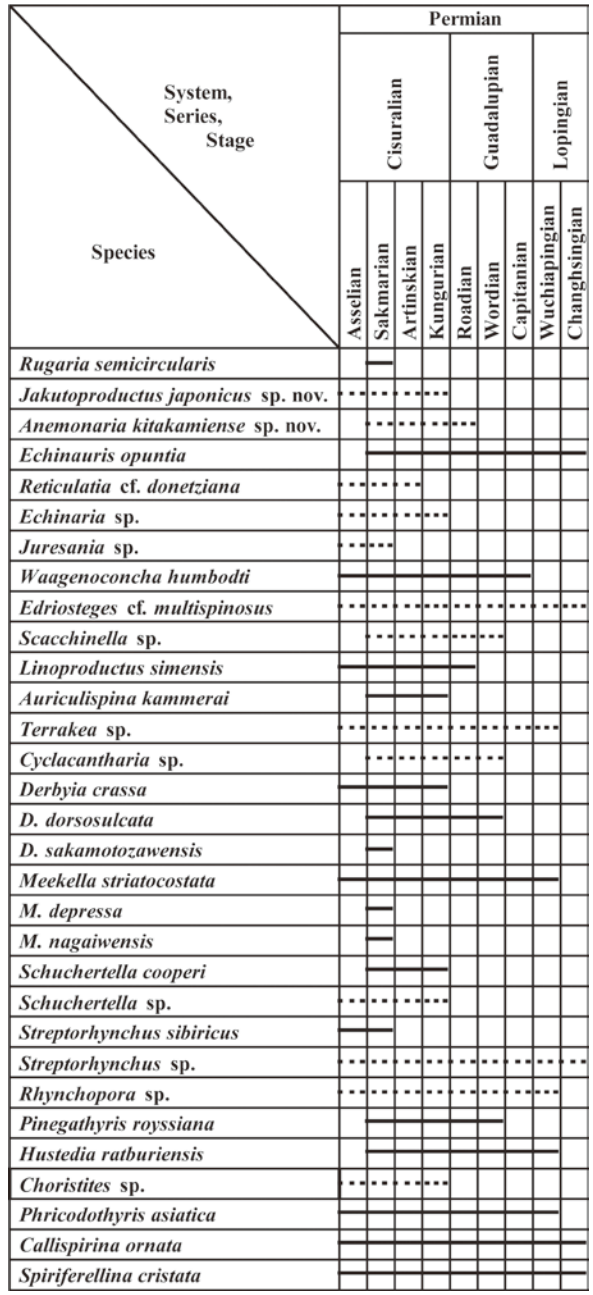

FIGURE 11. Stratigraphic distributions of brachiopod species of the SK1 assemblage in the Sakamotozawa fauna. Broken line shows range of the genus.

thick) and an upper part (the SK4 Unit: sandstone and limestone with subordinate shale, 120 m thick; Fig. 8). Brachiopod fossils were collected from four localities (SSK5, SSK14, SSK27 and SSK 28) in the SK1 Unit, and one locality (SSK24) in the SK4 Unit (Fig. 7). The Sakamotozawa Formation unconformably overlies the upper Carboniferous (Pennsylvanian) Nagaiwa Formation (Minato, 1942; Yamada, 1959; Kanmera and Mikami, 1965a; Mikami, 1965). The boundary between the SK2

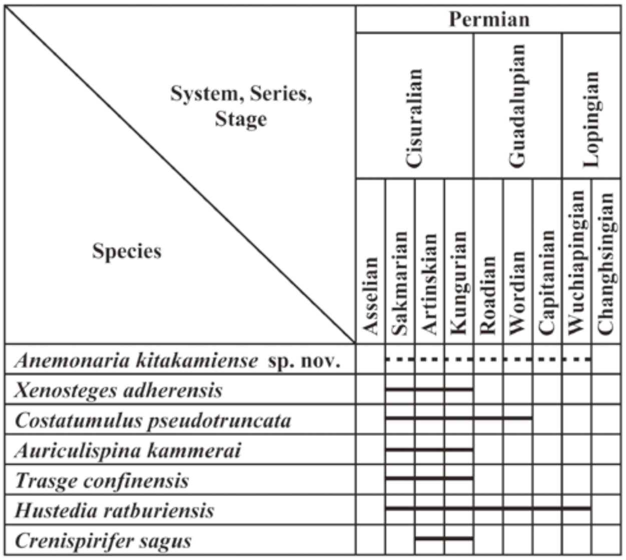

FIGURE 12. Stratigraphic distributions of brachiopod species of the SK4 assemblage in the Sakamotozawa fauna. Broken line shows range of the genus.

Unit and the SK3 Unit is a disconformity as noted by Mikami (1965) and Kanmera and Mikami (1965a).

Kanokura Formation

The Kanokura Formation is represented in the Nagaiwa–Sakamotozawa area only by the lower part (KN1 Unit); the middle and upper parts (KN2 and KN3 Units) are absent, although they are developed in the Setamai area. The KN1 Unit (460 m thick) consists mostly of sandstone and shale, with a thin (1–5 m thick) basal conglomerate (Fig. 9). Brachiopod fossils were collected from greenish-grey fine-grained sandstone 30 m above the base of the Kanokura Formation at locality SSK17 (Fig. 7). The boundary between the Kanokura Formation and the underlying Sakamotozawa Formation is an angular unconformity in the Nagaiwa–Sakamotozawa area (Choi et al., 1979; Shintani, 2009) as well as in the Setamai area (Minato et al., 1954).

MATERIALS AND FOSSIL LOCALITIES

The brachiopods described herein were collected from six localities (stations): four localities (SSK5, SSK14, SSK27 and SSK28) in the SK1 Unit, one locality (SSK24) in the SK4 Unit, and one locality (SSK17) in the KN1 Unit. The topographic and stratigraphic locations, lithologies and brachiopod species of the seven fossil localities are indicated in Figs. 7–10 and summarized below.

SSK5: Roadcut at 30 m west of junction of the Sakamotozawa and Shiratorizawa valleys (39°08’04” N, 141°38’52” E;

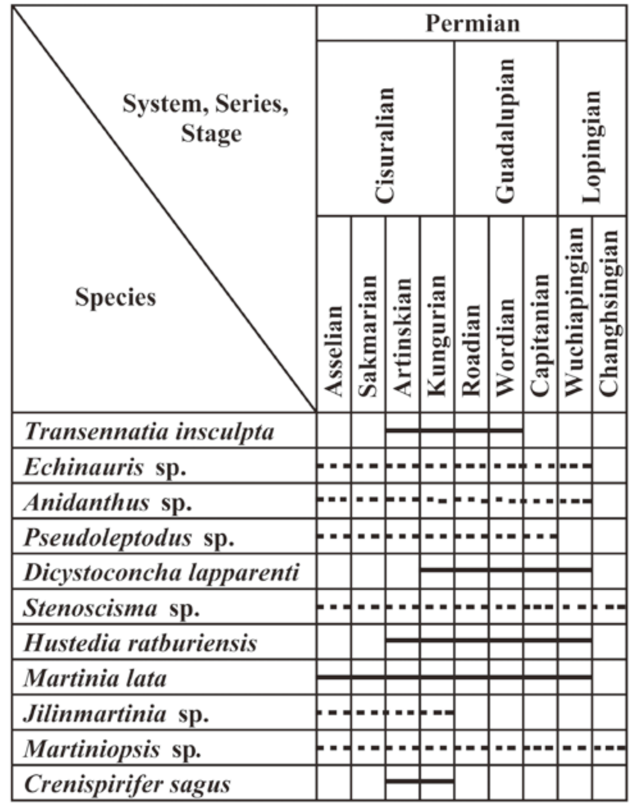

FIGURE 13. Stratigraphic distributions of brachiopod species of the KN1 assemblage in the Kanokura fauna. Broken line shows range of the genus.

Figs. 7, 8), grey calcareous medium-grained sandstone, top of the SK1 Unit, with *Rhynchopora* sp.

SSK14: Roadcut at 500 m west of Tashiroyashiki (39°08’17” N, 141°39’12” E; Figs. 7, 8), grey medium to coarse-grained sandstone, middle part of the SK1 Unit, with *Terrakea* sp., *Cyclacantharia* sp., *Derbyia crassa*, *D. dorsosulcata*, *D. sakamotozawensis*, *Meekella striatocostata*, *M. nagaiwensis*, *Streptorhynchus sibiricus*, *Pinegathyris royssiana*, *Choristites* sp. and *Spiriferellina cristata*.

SSK17: Roadcut at northern slope of Mt. Tashiroyama, 630 m SE of Nagaiwa (39°08’36” N, 141°39’04” E; Figs. 4, 7, 9), dark grey to light greenish-brown fine-grained sandstone, 30 m above the base of the Kanokura Formation, lower part of the KN1 Unit, with *Transennatia insculpta*, *Echinauris* sp., *Anidanthus* sp., *Pseudoleptodus* sp., *Dicystoconcha lapparenti*, *Stenoscisma* sp., *Hustedia ratburiensis*, *Martinia lata*, *Jilinmartinia* sp., *Martiniopsis* sp. and *Crenispirifer sagus*.

SSK24: Roadcut at 880 m south of Nagaiwa (39°08’25” N, 141°38’33” E; Figs. 7. 8), light grey fine-grained sandstone, lower part of the SK4 Unit, with *Anemonaria kitakamiense* sp. nov., *Xenosteges adherens*, *Costatumulus pseudotruncata*,

Species / Region	Japan			USA										Canada		N. Russia							Norway				Slovenia	Austria	W. Russia		C. Russia	Uzbekistan	NW China	N. China		NE China		E. Russia	E. China		CS China		SW China			Thailand			Pakistan	
	1. South Kitakami Belt	2. Hida Gaien Belt	3. Mizukoshi	4. Michigan	5. Ohio	6. Kentucky	7. Iowa	8. Missouri	9. Nebraska	10. Kansus	11. Oklahoma	12. New Mexico	13. Arizona	14. Yukon Territory	15. Ellesmere Island	16. Kolyma	17. Pechora Basin	18. Northan Urals	19. Vaygach Island	20. Timan	21. Kanin Peninsula	22. Pinega	23. Spitsbergen	24. Greenland	25. Germany	26. Hungary	27. Karavanke Mts.	28. Carnic Alps	29. Moscow Basin	30. Transcaucasus	31. Southern Urals	32. Fergana	33. Xinjiang	34. Inner Mongolia	35. Shanxi	36. Heilongjiang	37. Jilin	38. South Primorye	39. Shandong	40. Zhejiang	41. Hunan	42. Guangxi	43. Guizhou	44. Sichuan	45. Xizang (Tibet)	46. NC Thailand	47. S. Thailand	48. Timor	49. Salt Range	50. Bolivia
Rugaria semicircularis	+																																																	
Jakutoproductus japonicus sp. nov.	+																																																	
Anemonaria kitakamiense sp. nov.	+																																																	
Echinauris opuntia	+																																					+				+			+			+	+	
Reticulatia cf. *donetziana*	+																																																	
Echinaria sp.	+																																																	
Juresania sp.	+																																																	
Waagenoconcha humboldti	+																+	+		+									+					+				+												+
Edriosteges cf. *multispinosus*	+																																																	
Scacchinella sp.	+																																																	
Linoproductus simensis	+													+				+													+	+		+										+						
Auriculispina kanmerai	+																																																	
Terrakea sp.	+																																																	
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D. dorsosulcata	+																																	+																
D. sakamotozawensis	+																																																	
Meekella striatocostata	+				+	+	+	+	+	+		+																			+											+						+		
M. depressa	+																										+	+																						
M. nagaiwensis	+																																																	
Schuchertella cooperi	+																																														+			
Schuchertella sp.	+																																																	
Streptorhynchus sibiricus	+															+																																		
Streptorhynchus sp.	+																																																	
Rhynchopora sp.	+																																																	
Pinegathyris royssiana	+																			+	+	+	+	+							+																			
Hustedia ratburiensis	+	+	+																																											+	+			
Choristite sp.	+																																																	
Phricodothyris asiatica	+														+		+													+	+		+	+	+				+	+	+	+	+	+		+				
Spiriferellina cristata	+																	+		+				+	+	+		+			+		+	+	+	+														
Callispirina ornata	+																	+	+	+									+		+					+	+												+	

FIGURE 14. Geographic distributions of brachiopod species of the SK1 assemblage in the Sakamotozawa fauna.

Auriculispina kanmerai, *Trasgu confinensis*, *Hustedia ratburiensis* and *Crenispirifer sagus*.

SSK27: Upper stream of the Imahorazawa Valley (39°09'09" N, 141°38'57" E; Figs. 3A, 7, 8), dark grey fine-grained sandstone, lower part of the SK1 Unit, with *Rugaria semicircularis*, *Jakutoproductus japonicus* sp. nov., *Anemonaria kitakamiense* sp. nov., *Echinauris opuntia*, *Reticulatia* cf. *donetziana*, *Echinaria* sp., *Juresania* sp., *Waagenoconcha humboldti*, *Scacchinella* sp., *Linoproductus simensis*, *Auriculispina kanmerai*, *Meekella striatocostata*, *M. depressa*, *M. nagaiwensis*, *Schuchertella cooperi*, *Schuchertella* sp., *Streptorhynchus* sp., *Hustedia ratburiensis*, *Choristites* sp., *Phricodothyris asiatica*, *Callispirina ornata* and *Spiriferellina cristata*.

SSK28: Roadcut at the upper Imahorazawa Valley (39°09'10" N, 141°38'56" E; Figs. 3A, 3B, 7, 8), grey medium to coarse-grained sandstone, middle part of the SK1 Unit, with *Edriosteges* cf. *multispinosus*, *Terrakea* sp., *Derbyia crassa*, *D. dorsosulcata*, *Meekella striatocostata*, *M. nagaiwensis*, *Rhynchopora* sp., *Hustedia ratburiensis*, *Callispirina ornata* and *Spiriferellina cristata*.

BRACHIOPOD FAUNAS

The brachiopods described herein are the following 44 species in 37 genera, including two new species (*Jakutoproductus japonicus* sp. nov. and *Anemonaria kitakamiense* sp. nov.): *Rugaria semicircularis* Afanasjeva, Tazawa and Shintani, 2015, *Jakutoproductus japonicus* sp. nov., *Transennatia insculpta* (Grant, 1976), *Anemonaria kitakamiense* sp. nov., *Echinauris opuntia* (Waagen, 1884), *Echinauris* sp., *Reticulatia* cf. *donetziana* (Licharew, 1938), *Echinaria* sp.,

FIGURE 15. Sakmarian reconstruction map of the world (adapted from Ziegler et al., 1997), showing the geographic distributions of brachiopod species of the SK1 assemblage in the Sakamotozawa fauna. Solid circles indicate numbers of brachiopod species listed in the SK1 assemblage. Station numbers are same in Fig. 14.

Juresania sp., *Waagenoconcha humboldti* (d'Orbigny, 1842), *Edriosteges* cf. *multispinosus* Muir-Wood and Cooper, 1960, *Xenosteges adherens* Muir-Wood and Cooper, 1960, *Scacchinella* sp., *Linoproductus simensis* (Tschernyschew, 1902), *Costatumulus pseudotruncata* (Ustritsky, 1960), *Anidanthus* sp., *Auriculispina kanmerai* Tazawa and Shintani, 2015, *Terrakea* sp., *Cyclacantharia* sp., *Pseudoleptodus* sp., *Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974, *Derbyia crassa* (Meek and Hayden, 1858), *D. dorsosulcata* Liu and Waterhouse, 1985, *D. sakamotozawensis* Shintani, 2011, *Meekella striatocostata* (Cox, 1857), *M. depressa* Schellwien, 1900b, *M. nagaiwensis* Shintani, 2011, *Schuchertella cooperi* Grant, 1976, *Schuchertella* sp., *Streptorhynchus sibiricus* Zavodowsky, 1968, *Streptorhynchus* sp., *Stenoscisma* sp., *Rhynchopora* sp., *Trasgu confinensis* (Schellwien, 1892), *Pinegathyris royssiana* (von Keyserling, 1846), *Hustedia ratburiensis* Waterhouse and Piyasin, 1970, *Martinia lata* Grabau, 1936, *Jilinmartinia* sp., *Martiniopsis* sp., *Choristites* sp., *Phricodothyris asiatica* Chao, 1929, *Callispirina ornata* (Waagen, 1883), *Spiriferellina cristata* (von Schlotheim, 1816) and *Crenispirifer sagus* Cooper and Grant, 1976b.

The brachiopods of Nagaiwa–Sakamotozawa is classified into two faunas and three assemblages: the Sakamotozawa fauna (the SK1 and SK4 assemblages) and the Kanokura fauna (the KN1 assemblage).

Sakamotozawa fauna

SK1 assemblage

The SK1 assemblage, from the SK1 Unit of the Sakamotozawa Formation (localities SSK5, SSK14, SSK27 and SSK28), includes 31 species in 25 genera, with two new species (*Jakutoproductus japonicus* sp. nov. and *Anemonaria kitakamiense* sp. nov.). The species are *Rugaria semicircularis*, *Jakutoproductus japonicus* sp. nov., *Anemonaria kitakamiense* sp. nov., *Echinauris opuntia*, *Reticulatia* cf. *donetziana*, *Echinaria* sp., *Juresania* sp., *Waagenoconcha humboldti*, *Edriosteges* cf. *multispinosus*, *Scacchinella* sp., *Linoproductus simensis*, *Auriculispina kanmerai*, *Terrakea* sp., *Cyclacantharia* sp., *Derbyia crassa*, *D. dorsosulcata*, *D. sakamotozawensis*, *Meekella striatocostata*, *M. depressa*, *M. nagaiwensis*, *Schuchertella cooperi*, *Schuchertella* sp., *Streptorhynchus sibiricus*, *Streptorhynchus* sp., *Rhynchopora* sp., *Pinegathyris royssiana*, *Hustedia ratburiensis*, *Choristites* sp., *Phricodothyris asiatica*, *Callispirina ornata* and *Spiriferellina cristata*. Of these species, *Rugaria semicircularis*, *Jakutoproductus japonicus* sp. nov., *Waagenoconcha humboldti*, *Linoproductus simensis*, *Auriculispina kanmerai*, *Derbyia crassa*, *D. dorsosulcata*, *D. sakamotozawensis*, *Hustedia ratburiensis*, *Choristites* sp., *Phricodothyris asiatica* and *Spiriferellina cristata* are abundant; *Terrakea* sp., *Meekella striatocostata*, *M. depressa* and *M. nagaiwensis* are common; and the other species are rare (Fig.

Species \ Region	Japan			USA	Slovenia		NW China	N. China	E. China	CS China			Thailand		
	1. South Kitakami Belt	2. Hida Gaien Belt	3. Mizukoshi	4. Texas	5. Karavanke Mountains	6. Afghanistan	7. Xinjiang	8. Inner Mongolia	9. Zhejiang	10. Hubei	11. Guangdong	12. Guangxi	13. NC Thailand	14. S. Thailand	15. Malaysia
Transennatia insculpta	+													+	+
Anemonaria kitakamiense sp. nov.	+														
Echinauris sp.	+														
Xenosteges adherens	+			+											
Costatumulus pseudotruncata	+						+	+							
Anidanthus sp.	+														
Auriculispina kanmerai	+														
Pseudoleptodus sp.	+														
Dicystoconcha lapparenti	+					+		+	+	+	+				
Stenoscisma sp.	+														
Trasgu confinensis	+				+										
Hustedia ratburiensis	+	+	+										+	+	
Martinia lata	+											+			
Jilinmartinia sp.	+														
Martiniopsis sp.	+														
Crenispirifer sagus	+			+											

FIGURE 16. Geographic distributions of brachiopod species of the SK4 assemblage in the Sakamotozawa fauna and the KN1 assemblage in the Kanokura fauna.

10).

SK4 assemblage

The SK4 assemblage, from the SK4 Unit of the Sakamotozawa Formation (locality SSK24), includes seven species in seven genera: *Anemonaria kitakamiense* sp. nov., *Xenosteges adherens*, *Costatumulus pseudotruncata*, *Auriculispina kanmerai*, *Trasgu confinensis*, *Hustedia ratburiensis* and *Crenispirifer sagus*. Of these species, *Anemonaria kitakamiense* sp. nov. and *Crenispirifer sagus* are abundant; *Trasgu confinensis* is common; and the other species are rare (Fig. 10).

Kanokura fauna

KN1 assemblage

The KN1 assemblage, from the KN1 Unit of the Kanokura Formation (locality SSK17), includes 11 species in 11 genera: *Transennatia insculpta*, *Echinauris* sp., *Anidanthus* sp., *Pseudoleptodus* sp., *Dicystoconcha lapparenti*, *Stenoscisma* sp., *Hustedia ratburiensis*, *Martinia lata*, *Jilinmartinia* sp., *Martiniopsis* sp. and *Crenispirifer sagus*. Of these species, *Transennatia insculpta* and *Echinauris* sp. are abundant; *Martinia lata* is common; and the other species are rare (Fig. 10).

AGE AND CORRELATION

Sakamotozawa Formation

Lower part of the Sakamotozawa Formation

The stratigraphic distributions of the brachiopod species of the SK1 assemblage are described in the "Systematic descriptions" section of the present paper, and summarized in Fig. 11. Of the brachiopods listed above, four species (*Rugaria semicircularis*, *Derbyia sakamotozawensis*, *Meekella depressa* and *M. nagaiwensis*) are known only from the Sakmarian; *Streptorhynchus sibiricus* is known from the Asselian–Sakmarian; *Derbyia crassa* from the Moscovian–Kungurian; *Linoproductus simensis* from the Kasimovian–Roadian; *Meekella striatocostata* from the Bashkirian–Wordian; and *Waagenoconcha humboldti* from the Gzhelian–Capitanian. In contrast, two species (*Auriculispina kanmerai* and *Schuchertella cooperi*) are known from the Sakmarian–Kungurian; another two species (*Derbyia dorsosulcata* and *Pinegathyris royssiana*) from the Sakmarian–Wordian; and *Hustedia ratburiensis* from the Sakmarian–Wuchiapingian. The other species are long-ranging: *Echinauris opuntia* has a range of Sakmarian–Changhsingian; *Phricodothyris asiatica* of Moscovian–Wuchiapingian; and two species (*Callispirina ornata* and *Spiriferellina cristata*) of Kasimovian–Changhsingian. At the generic level, *Jakutoproductus* is known from the Asselian–Kungurian (Brunton et al., 2000); *Reticulatia* from the Bashkirian–Artinskian (Brunton et al., 2000); *Echinaria* from the Gzhelian–Kungurian (Brunton et al., 2000); *Juresania* from the Kasimovian–Sakmarian (Brunton et al., 2000; this study); *Edriosteges* from the Asselian–Changhsingian (Shen et al., 1992; Brunton et al., 2000); *Scacchinalla* from the Sakmarian–Wordian (Brunton et al, 2000; Tazawa and Araki, 1999); *Terrakea* from the Asselian–Wuchiapingian (Brunton et al., 2000); and *Cyclacantharia* from the Sakmarian–Wordian (Brunton et al., 2000; this study). The other genera are long-ranging: *Schuchertella* has a range of Late Devonian–early Permian (Williams and Brunton, 2000); *Streptorhynchus* of Carboniferous–Permian (Williams and Brunton, 2000); *Rhynchopora* of Tournaisian–Tatarian (Savage, 2002); and *Choristites* of Mississsippian?–Cisuralian? (Carter, 2006). In summary, the age of the SK1 assemblage is identified as Sakmarian.

As discussed above, the SK1 assemblage is identified as Sakmarian; thus, the lower part of the Sakamotozawa Formation (SK1 Unit) is correlated with the Sakmarian. This conclusion is consistent with the previous study (Ueno et al., 2007); in which the age of the lowest part of the Sakamotozawa Formation is assigned to the Sakmarian based on some fusulines, *Schubertella* sp., *Quasifusulina*? sp., *Rugosofusuina* sp., *Eoparafusulina* aff. *perplexa* (Grozdilova and Lebedeva) and *Nipponitella explicata* Hanzawa.

Upper part of the Sakamotozawa Formation

The stratigraphic distributions of the brachiopod species of the SK4 assemblage are described in the "Systematic descriptions" section of the present paper, and summarized in Fig. 12. Of the brachiopod species listed above, four species (*Xenosteges adherens*, *Costatumulus pseudotruncata*,

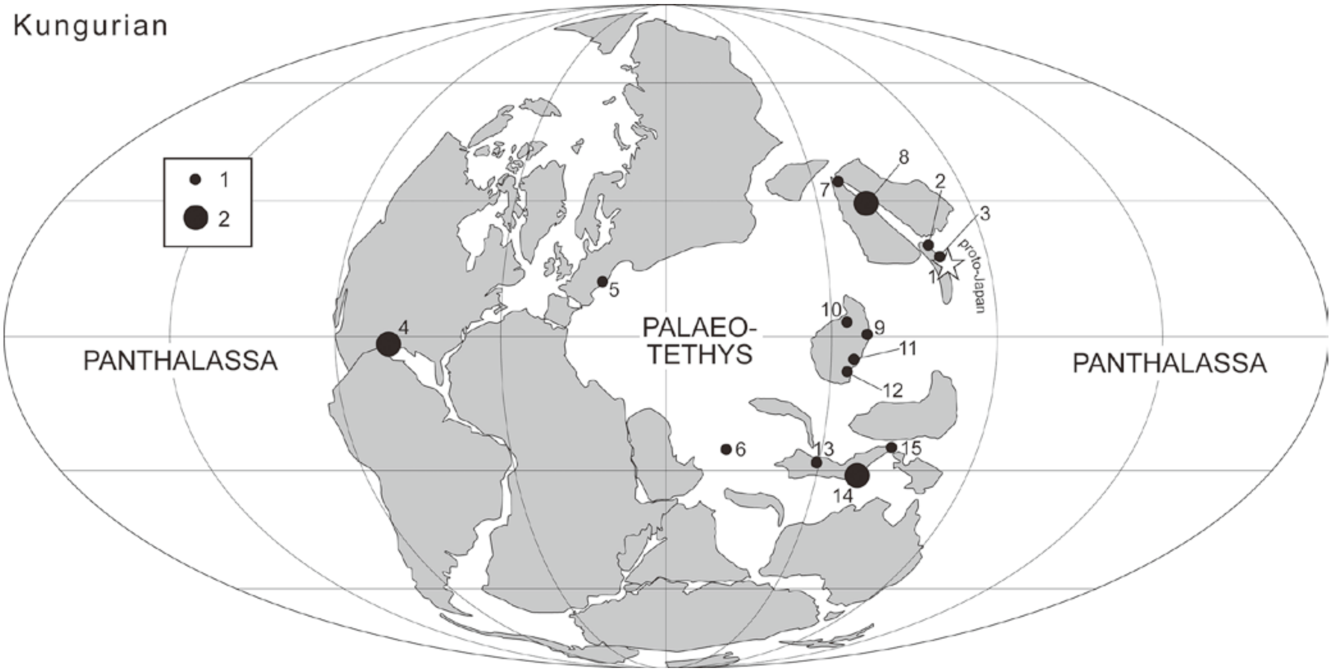

FIGURE 17. Kungurian reconstruction map of the world (adapted from Ziegler et al., 1997), showing the geographic distributions of brachiopod species of the SK4 assemblage in the Sakamotozawa fauna and the KN1 assemblage in the Kanokura fauna. Solid circles indicate numbers of brachiopod species listed in the SK4 and KN1 assemblages. Station numbers are same in Fig. 16.

Auriculispina kanmerai and *Trasgu confinensis*) are known from the Sakmarian–Kungurian; *Hustedia ratburiensis* from the Sakmarian–Wuchiapingian; and *Crenispirifer sagus* from the Artinskian–Kungurian. At the generic level, *Anemonaria* is known from the Sakmarian–Wuchiapingian (Brunton et al., 2000; Tazawa, 2011). In summary, the SK4 assemblage is assigned to the Artinskian–Kungurian in age.

As discussed above, the SK4 assemblage is identified as Artinskian–Kungurian; thus, the upper part of the Sakamotozawa Formation (SK4 Unit) is correlated with the Artinskian−Kungurian. However, Ueno et al. (2009) concluded that the age of the upper part (SK4 Unit) of the Sakamotozawa Formation is Bolorian (= early Kungurian) on the basis of fusulines, *Pseudofusulina dzamantalensis* (Leven), *Darvasites minatoi* (Kanmera and Mikami), *Kubergandella*? sp. and *Misellina* sp. Therefore, the upper part of the Sakamotozawa Formation (SK4 Unit) is correlated with the lower Kungurian.

Kanokura Formation

Lower part of the Kanokura Formation

The stratigraphic distributions of the brachiopod species of the KN1 assemblage are described in the "Systematic descriptions" section of the present paper, and summarized in Fig. 13. Of the brachiopods listed above, *Transennatia insculpta* is known from the Artinskian–Wordian; *Dicystoconcha lapparenti* from the Kungurian–Wuchiapingian; *Hustedia ratburiensis* from the Artinskian–Wuchiapingian; *Martinia lata* from the Asselian–Wuchiapingian; and *Crenispirifer sagus* from the Artinskian–Kungurian. At the generic level, *Echinauris* is known from the Gzhelian–Wuchiapingian (Cooper and Grant, 1975; Brunton et al., 2000; Shen and Zhang, 2008); *Anidanthus* from the Asselian–Wuchiapingian (Brunton et al., 2000; Klets, 2005); *Pseudoleptodus* from the Asselian–Capitanian (Cooper and Grant, 1974; Grant, 1976; this study); *Stenoscisma* from the lower Carboniferous to the Changhsingian (Shen et al., 2000; Carlson and Grant, 2002); *Jilinmartinia* from the Moscovian–Kungurian (Pavlova, 1991; Carter and Gourvennec, 2006); and *Martiniopsis* from the upper Carboniferous to the Lopingian (Carter and Gourvennec, 2006). In summary, the KN1 assemblage is identified as Kungurian in age. The lower part of the Kanokura Formation (KN1 Unit) in the Nagaiwa–Sakamotozawa area is probably correlated with the upper Kungurian, considering that the base of the Kanokura Formation (KN1 Unit) covers the upper part of the Sakamotozawa Formation (SK4 Unit) with an angular unconformity in broad area of the South Kitakami Belt (e.g., Minato et al., 1954; Choi et al., 1979).

PALAEOBIOGEOGRAPHY

Sakmarian

The geographic distributions of the Sakmarian brachiopod species of the SK1 assemblage are described in the "Systematic descriptions" section of the present paper, and are summarized in Figs. 14 and 15. Of the 31 species of the SK1 assemblage, six species also occur in central Russia (southern Urals); five species have been reported from northern China (Inner Mongolia); four species are found in northern Russia (northern Urals and Timan); and three species also occur in central-southern China (Guangxi). To summarize, the SK1 assemblage has a close affinity with the Sakmarian brachiopod faunas of central Russia (southern Urals), northern Russia (northern Urals and Timan) and northern China (Inner Mongolia). Furthermore, the SK1 assemblage includes both antitropical genera (*Jakutoproductus*, *Anemonaria*, *Juresania*, *Waagenoconcha*, *Auriculispina*, *Terrakea*, *Rhynchopora*, *Pinegathyris* and *Choristites*) and tropical genera (*Echinauris*, *Scacchinella*, *Cyclacantharia* and *Meekella*). Thus, the Sakmarian brachiopod fauna (SK1 assemblage) is a mixed Boreal–Tethyan fauna with a predominance of the Boreal elements, and exhibits affinities with those of central Russia (southern Urals), northern Russia (northern Urals and Timan) and northern China (Inner Mongolia).

This conclusion is consistent with the previous works on the Sakmarian brachiopod faunas of the Nagaiwa–Sakamotozawa area (Tazawa and Shintani, 2010, 2015) and from the Kamiyasse area (Tazawa and Shintani, 2014).

Kungurian

The geographic distributions of the Kungurian brachiopod species of the SK4 and KN1 assemblages are described in the "Systematic descriptions" section, and are summarized in Figs. 16 and 17. Among the 16 species of the SK4 and KN1 assemblages, two species also occur in the USA (Texas) and southern Thailand; and one species has been reported from central Japan (Hida Gaien Belt), southwestern Japan (Mizukoshi), Slovenia, Afghanistan, northwestern China (Xinjiang), northern China (Inner Mongolia), eastern China (Zhejiang), central-southern China (Hubei, Guangdong and Guangxi), north-central Thailand and Malaysia. To summarize, the Kungurian fauna (SK4 and KN1 assemblages) somewhat resembles those of the USA (Texas) and southern Thailand. In addition, the Kungurian brachiopod fauna (SK4 and KN1 assemblages) includes both antitropical genera (*Anemonaria*, *Costatumulus*, *Anidanthus*, *Auriculispina* and *Jilinmartinia*) and tropical genera (*Transennatia*, *Echinauris*, *Xenosteges*, *Pseudoleptodus* and *Dicystoconcha*). It is noteworthy that *Jilinmartinia* occurs mostly from northwestern China to northeastern China (Shen et al., 2017). Thus, the Kungurian brachiopod fauna (SK4 and KN1 assemblages) is a mixed Boreal–Tethyan–Panthalassan fauna, and exhibits affinities with those of northwestern–northeastern China.

This conclusion is consisted with previous work (Tazawa and Nakamura, 2015), which described a Kungurian brachiopod fauna consisting of 15 species in 15 genera from the basal part of the Hosoo Formation in the Nakadaira area in the South Kitakami Belt. The Nakadaira fauna is also a mixed Boreal–Tethyan fauna, and exhibits a close affinity with the early Permian brachiopod faunas of northwestern China (Xinjiang) and northern China (Inner Mongolia).

DISCUSSION: CISURALIAN GEOGRAPHY AND BIOGEOGRAPHY OF THE SOUTH KITAKAMI BELT

From the information provided above, we can conclude that early Permian (Sakmarian–Kungurian) brachiopod faunas of the South Kitakami Belt are characterized by a mixture of both Boreal and Tethyan elements, and belong to a transitional zone between the Boreal and Tethyan realms in the Northern Hemisphere, i.e., the Northern Transitional Zone (Shi et al., 1995) [= the Inner Mongolian–Japanese Transisional Zone (Tazawa, 1991) and the Sino–Mongolian–Japanese Province (Shi and Tazawa, 2001)]. Shen et al. (2013) noted that the Northern Transitional Zone between the Boreal and the Tethyan realms was not recognized before Kungurian based on an analysis of global database; however, it is clear that the zone was present in the Sakmarian–Kungurian in terms of the faunas described herein. The South Kitakami region belonged to the Northern Transitional Zone in the Northern Hemisphere, and was probably a shallow sea bordering a microcontinent (the Proto-Japan Block) at the eastern end of the Central Asian Orogenic Belt and near and to the east of the North China Block during the Sakmarian–Kungurian.

The co-occurrence of the Permian coral groups Durhaminidae and Waagenophyllidae in the lower Permian strata of the South Kitakami Belt (Minato and Kato, 1965a, 1965b. 1970), as noted by Tazawa (2018), indicates that the South Kitakami region was located in a transitional zone between the Boreal and Tethyan realms. The area probably lay near the North China Block, which was located at midlatitudes of the Northern Hemisphere during the early Permian.

Among early Permian land plants, the Maiya flora (Asama, 1967, 1981) from the Nishigori Formation of Maiya closely resembles that of northern Korea (Sadon), and the Setamai flora (Asama and Murata, 1974) from the Sakamotozawa Formation of Setamai is similar to that of northern China (Shanxi). Thus, the early Permian Maiya and Setamai floras of the South Kitakami Belt have affinities with those of the North China Block, which belonged to the Cathaysia Northern Subprovince during the Permian (Huang and Chen, 1987).

Some objections to the placement of the South Ktakami region near the North China Block were listed by Ehiro (2001), Okawa et al. (2013) and Isozaki et al. (2017) who placed the South Kitakami region near the South China Block or as part of the Greater South China during the Permian. However, the early Permian brachiopod faunas of southern China (Jin et al., 1974; Yang et al., 1977; Liu et al., 1982) completely lack the Boreal (antitropical) genera such as *Jakutoproductus* and *Rhynchopora* in the Sakmarian faunas, and *Anemonaria*, *Costatumulus* and

Jilinmartinia in the Kungurian faunas.

CONCLUSIONS

In this study, early Permian (Cisuralian) brachiopods are described from the lower part (SK1 Unit) and the upper part (SK4 Unit) of the Sakamotozawa Formation and the lower part (KN1 Unit) of the Kanokura Formation in the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeastern Japan. A total of 44 species in 37 genera are described, of which two (*Jakutoproductus japonicus* sp. nov. and *Anemonaria kitakamiense* sp. nov.) are new. In terms of biostratigraphy, the lower part of the Sakamotozawa Formation is correlated with the Sakmarian; the upper part of the Sakamotozawa Formation is corelated with the lower Kungurian; and the lower part of the Kanokura Formation is correlated with the upper Kungurian. Palaeobiogeographically, the Sakmarian fauna (the SK1 assemblage from the SK1 Unit) is a mixed Boreal–Tethyan fauna with a predominance of the Boreal elements. The assemblage exhibits a close affinity with those of central Russia (southern Urals), northern Russia (northern Urals and Timan) and northern China (Inner Mongolia). The Kungurian fauna (the SK4 assemblage from the SK4 Unit and the KN1 assemblage from the KN1 Unit) is a mixed Boreal–Tethyan–Panthalassan fauna, and exhibits affinities with those of northwestern–northeastern China. We conclude that the South Kitakami region, including the Nagaiwa–Sakamotozawa area, belonged to the Northern Transitional Zone of Shi et al. (1995), and was probably a shallow sea bordering the newly proposed Proto-Japan Block, which was located at near and to the east of the North China Block at the eastern end of the Central Asian Orogenic Belt during the Sakmarian–Kungurian.

SYSTEMATIC DESCRIPTIONS
(by J. Tazawa)

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

Order 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 *RUGARIA* Cooper and Grant, 1969

Type species.—*Chonetes hessensis* King, 1931.

Rugaria semicircularis Afanasjeva, Tazawa and Shintani, 2015
(Fig. 18F–H)

Rugaria semicircularis Afanasjeva, Tazawa and Shintani, 2015, p. 23, pl. 3, figs. 1–6.

Material.—Six specimens from locality SSK27: (1) ventral internal mould and dorsal external mould of a conjoined shell, NU-B1830; and (2) external and internal moulds of four ventral valves, NU-B1826, 1827 (holotype), 1828, 1829.

Remarks.—These specimens were described by Afanasjeva et al. (2015, p. 3, pl. 3, figs. 1–6) as *Rugaria semicircularis* Afanasjeva, Tazawa and Shintani, 2015 from the SK1 Unit of the Sakamotozawa Formation in the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeastern Japan. *Rugaria semicircularis* resembles the type species, *Rugaria hessensis* (King, 1931), redescribed by Cooper and Grant (1975, p. 1296, pl. 496, figs. 18–25; pl. 498, figs. 1–12; pl. 499, figs. 70, 71) from the Hess Formation (Taylor Ranch Member) of Texas in size and shape of the shell, but differs in having thinner and more numerous capillae on both ventral and dorsal valves.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Suborder PRODUCTIDINA Waagen, 1883
Superfamily PRODUCTELLOIDEA Schuchert, 1929
Family AVONIIDAE Sarytcheva, 1960
Subfamily TUBERSULCULINAE Waterhouse, 1971
Genus *JAKUTOPRODUCTUS* Kaschirtzev, 1959a

Type species.—*Marginifera verchoyanica* Fredericks, 1931.

Jakutoproductus japonicus sp. nov.
(Fig. 18A–E)

Etymology.—Named after the country, Japan, including the fossil locality.

Material.—Six specimens from locality SSK27: (1) external and internal moulds of a ventral valve, NU-B2363; (2) internal mould of a ventral valve, NU-B2364; and (3) external and internal moulds of four dorsal valves, NU-B2365 (holotype), 2366–2368.

Diagnosis.—Small, transverse *Jakutoproducus*, with sparce spine bases on ventral valve.

Description.—Shell small in size for genus, transversely subrectangular in outline; hinge shorter than greatest width at about midlength; length 8 mm, width 11 mm in the best preserved ventral valve specimen (NU-B2363); length 7 mm, width 11 mm in the best preserved dorsal vale specimen (holotype, NU-B2365). Ventral valve moderately and unevenly convex in lateral profile, most convex at umbonal region; umbo small; ears small, triangular, not clearly differentiated from visceral portion; sulcus very shallow or absent. Dorsal valve flattened on visceral disc, geniculated and followed by short trail; ears small, distinct; fold narrow and low. External surface of ventral valve ornamented with numerous irregular concentric

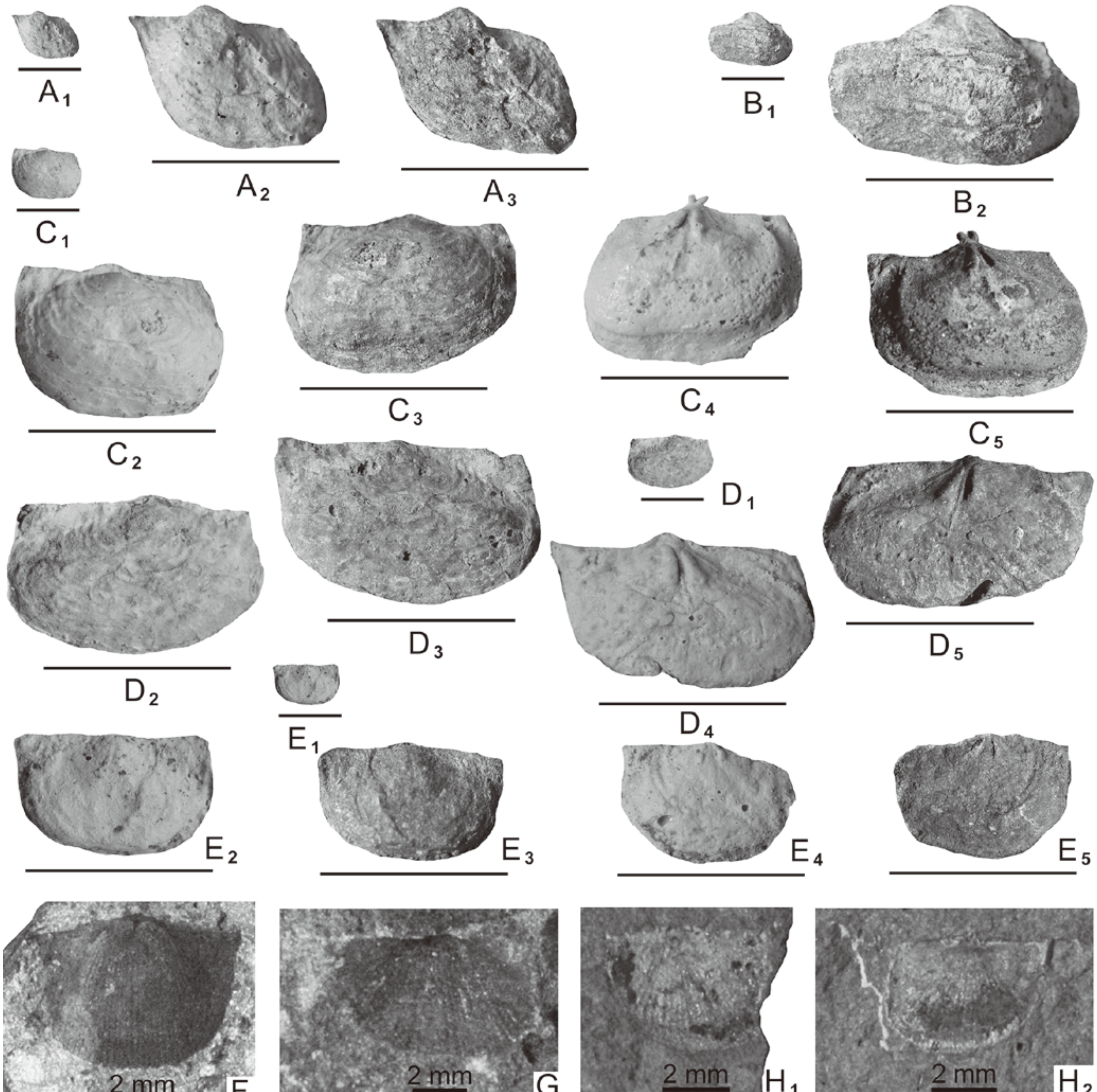

FIGURE 18. Brachiopods of the SK1 assemblage (1). **A–E,** *Jakutoproductus japonicus* sp. nov.; A, external latex cast (A_1, A_2) and internal mould (A_3) of ventral valve, NUB2363; B, external latex cast (B_1, B_2) of ventral valve, NU-B2364; C, external latex cast (C_1, C_2), external mould (C_3), internal latex cast (C_4) and internal mould (C_5) of dorsal valve, NU-B2365 (holotype); D, external latex cast (D_1, D_2), external mould (D_3), internal latex cast (D_4) and internal mould (D_5) of dorsal valve, NU-B2367; E, external latex cast (E_1, E_2), external mould (E_3), internal latex cast (E_4) and internal mould (E_5) of dorsal valve, NU-B2366; **F–H,** *Rugaria semicircularis* Afanasjeva, Tazawa and Shintani; F, internal mould of ventral valve, NU-B1827 (holotype); G, external mould of ventral valve, NU-B1828; H, external mould (H_1) and internal mould (H_2) of ventral valve, NU-B1829. Scale bars are 1 cm, except for those of F–H.

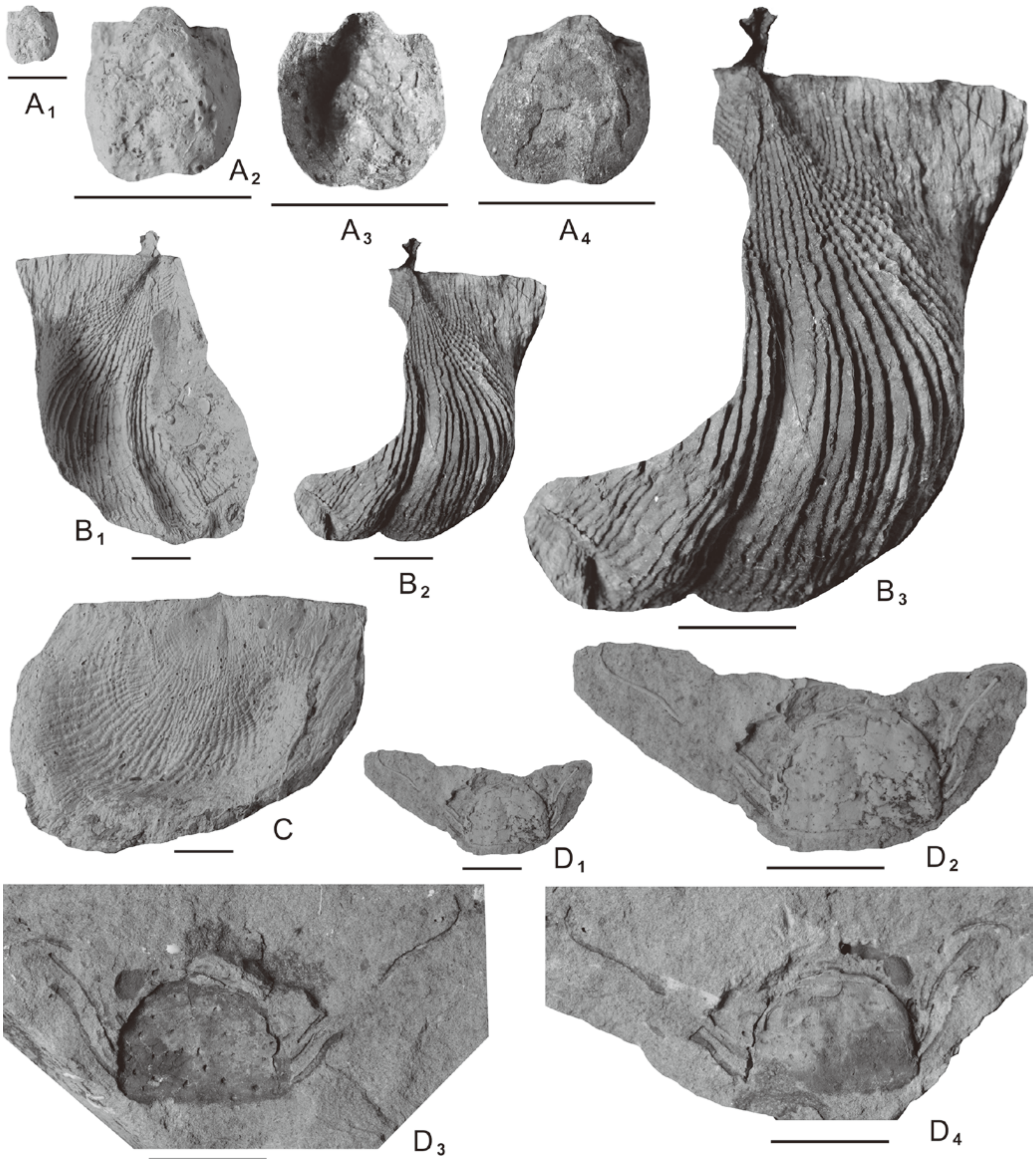

FIGURE 19. Brachiopods of the SK1 assemblage (2). **A,** *Anemonaria kitakamiense* sp. nov., ventral external latex cast (A1, A2), ventral external mould (A3) and dorsal internal mould (A4) of conjoined shell, NU-B2370; **B, C,** *Reticulatia* cf. *donetziana* (Licharew); B, external latex cast (B1) and internal mould (B2, B3) of dorsal valve, NU-B1873; C, external latex cast of dorsal valve, NU-B1874; **D,** *Echinauris opuntia* (Waagen), external latex cast (D1, D2), external mould (D3) and internal mould (D4) of ventral valve, NU-B1867. Scale bars are 1 cm.

rugae and sparse elongate spine bases. External ornament of dorsal valve consisting of numerous irregular lamellae and sparce dimples. Interior of ventral valve not well preserved. Dorsal interior with a bilobate cardinal process, a pair of elongate adductor scars, and a thin, long median septum extending to half valve length.

Remarks.—The present new species resembles the type species, *Jakutoproductus verchoyanicus* (Fredericks, 1931, p. 211, pl. 1, figs. 11–13) from the lower Permian of the Dulgalakh River, western Verkhoyansk, northern Russia, in size and outline of the shell, but differs in having sparce spine bases on the ventral valve. *Jakutoproductus crassus* Kaschirtzev, 1959b, redescribed by Abramov and Grigorjeva (1988, p. 115, pl. 5, figs. 15–19, 22–26; pl. 6, figs. 1, 2) from the lower Permian (Asselian–Artinskian) of Verkhoyansk, has also sparce spine bases on the ventral valve, but differs from *Jakutoproductus japonicus* sp. nov. in the larger size and in having distinct sulcus on the ventral valve. *Jakutoproductus tatjanae* Abramov and Grigorjeva (1983, p. 67, pl. 1, figs. 19–26), from the upper Carboniferous of Verkhoyansk, similar to the present new species in size and outline of the shell, but differs in having numerous spine bases on the ventral valve. The shells described by Shi (1994, p. 115, fig. 4) as *Jakutoproductus verchoyanicus* (Fredericks, 1931), from the lower Permian of northern Yukon Territory, Canada, has also sparce spine bases on the ventral valve, but differs from the present new species in its larger size and less transverse outline.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Superfamily MARGINIFEROIDEA Stehli, 1954
Family MARGINIFERIDAE Stehli, 1954
Subfamily MARGINIFERINAE Stehli, 1954
Genus *TRANSENNATIA* Waterhouse, 1975

Type species.—*Productus gratiosus* Waagen, 1884.

Transennatia insculpta (Grant, 1976)
(Fig. 32A–C)

Gratiosina insculpta Grant, 1976, p. 135, pl. 32, figs. 1–37; pl. 33, figs. 1–16.
Transennatia cf. *insculpta* (Grant). Sone in Sone et al., 2003, p. 528, figs. 7, 8c.
Transennatia insculpta (Grant). Chen, 2004, p. 14, pl. 2, figs. 5–12.

Material.—Six specimens from locality SSK17: (1) external and internal moulds of a ventral valve, NU-B2281; (2) external mould of a ventral valve, NU-B2282; (3) external and internal moulds of two dorsal valves, NU-B2283, 2284; (4) external mould of a dorsal valve, NU-B2285; and (5) internal mould of a conjoined shell, NU-B2286.

Remarks.—These specimens are referred to *Transennatia insculpta* (Grant, 1976), originally described by Grant (1976, p. 135, pl. 32, figs. 1–37; pl. 33, figs. 1–16) as *Gratiosina insculpta* Grant, 1976, from the Ratburi Formation of Ko Muk, southern Thailand, in the small and transverse shell (length 12 mm, width 19 mm in the best preserved dorsal valve specimen, NU-B2283) and the coarse reticulate ornament on the visceral discs of both ventral and dorsal valves. *Transennatia* cf. *insculpta* (Grant, 1976), described by Sone (in Sone et al., 2003, p. 528, figs. 7, 8c) from the middle Permian (Roadian–Wordian) of Johore, Peninsular Malaysia may be a synonym of *T. insculpta*. The type species, *Transennatia gratiosa* (Waagen, 1884, p. 691, pl. 72, figs. 3–7), from the Wargal and Chhidru Formations of the Salt Range, Pakistan, differs from *T. insculpta* in the larger size and in having finer reticulate ornament on the discs of both valves.

Occurrence.—KN1 Unit.

Distribution.—Artinskian–Wordian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), northwestern China (Xinjiang), southern Thailand (Ko Muk) and Malaysia.

Family PAUCISPINIFERIDAE Muir-Wood and Cooper, 1960
Subfamily PAUCISPINIFERINAE Muir-Wood and Cooper, 1960
Genus *ANEMONARIA* Cooper and Grant, 1969

Type species.—*Marginifera sublaevis* King, 1931.

Anemonaria kitakamiense sp. nov.
(Figs. 19A, 30A–C)

Etymology.—Named after the fossil locality, Kitakami Mountains.

Material.—Six specimens from localities SSK24 and SSK27: (1) external and internal moulds of four ventral valves, NU-B2325 (holotype), 2326, 2327, 2370; and (2) internal moulds of two ventral valves, NU-B2328, 2329.

Diagnosis.—Small, equidimentional *Anemonaria*, with small ears and low sulcus on ventral valve.

Description.—Shell small in size for genus, rounded subquadrate in outline, hinge slightly shorter than greatest width at about midlength; length 10 mm, width 11 mm in the holotype (NU-B2325). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region; umbo small, ears small, blunt; sulcus low on anterior half; lateral slopes steep. External surface of ventral valve nearly smooth except for a few faint costae on trail; a row of large spine bases, numbering 3 at base of each ears. Ventral interior with widely flabellate diductor scars and narrow elongate adductor scars

Remarks.—*Anemonaria kitakamiense* sp. nov. most resembles *Anemonaria sulankherensis* Manankov (1998, p. 52, pl. 8, figs. 8, 9), from the Tsaganul Horizon (Ufimian) of Mt. Dzhirem-Ula, southeastern Mongolia, in the small, rounded quadrate ventral valve with a low sulcus. But the Mongolian species differs from the present new species in being more

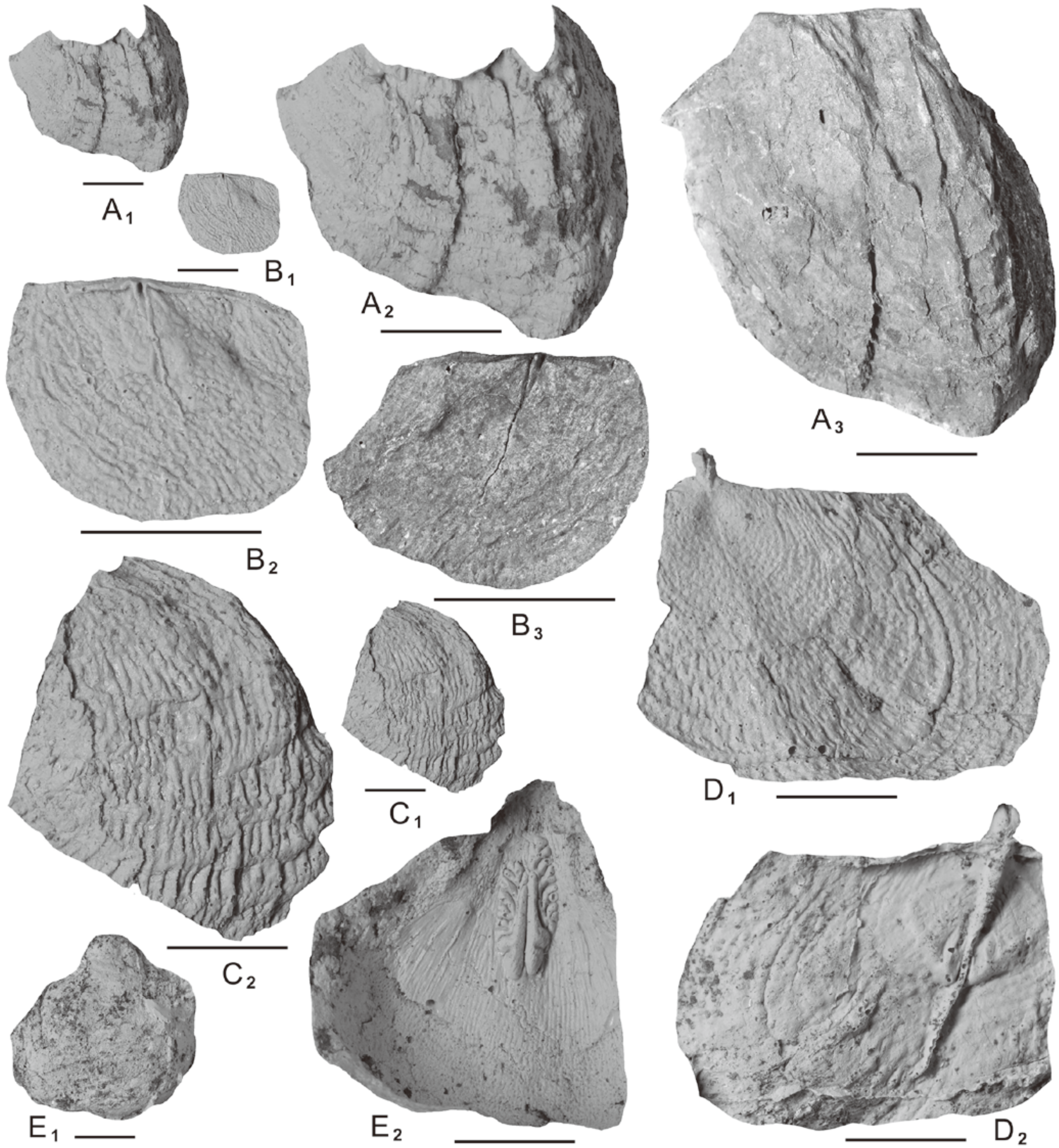

FIGURE 20. Brachiopods of the SK1 assemblage (3). **A,** *Echinaria* sp., external latex cast (A1, A2) and internal mould (A3) of ventral valve, NU-B1899; **B,** *Juresania* sp., internal latex cast (B1, B2) and internal mould (B3) of dorsal valve, NU-B1900; **C, D,** *Waagenoconcha humboldti* (d'Orbigny); C, external latex cast (C1, C2) of ventral valve, NU-B1282; D, external latex cast (D1) and internal latex cast (D2) of dorsal valve, NU-B1283; **E,** *Edriosteges* cf. *multispinosus* Muir-Wood and Cooper, external latex cast (E1) and internal latex cast (E2) of ventral valve, NU-B1868. Scale bars are 1 cm.

transverse outline. *Anemonaria sublaevis* (King, 1931), redescribed by Cooper and Grant (1975, p. 1103, pl. 408, figs. 1–26), from the Bone Spring, Cathedral Mountain and Road Canyon Formations of Texas in the USA, differs from *A. kitakamiense* sp. nov. in the transverse ventral valve with deeper sulcus. *Anemonaria auriculata* Shi and Waterhouse (1996, p. 68, pl. 6, figs. 10–28, text-figs. 22–24), from the upper Jungle Creek Formation of northern Yukon Territory, Canada, is also a small-sized *Anemonaria*, but differs from the Kitakami species in having alate ears and deep sulcus on the ventral valve.

Occurrence.—SK1 and SK4 units.

Distribution. —Sakmarian–Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Family COSTISPINIFERIDAE Muir-Wood and Cooper, 1960
Subfamily COSTISPINIFERINAE Muir-Wood and Cooper, 1960
Genus *ECHINAURIS* Muir-Wood and Cooper, 1960

Type species.—*Echinauris lateralis* Muir-Wood and Cooper, 1960.

Echinauris opuntia (Waagen, 1884)
(Fig. 19D)

Productus opuntia Waagen, 1884, p. 707, pl. 79, figs. 1, 2; Broili, 1916, p. 17, pl. 117, figs. 9, 10.
Echinauris opuntia (Waagen). Grant, 1968, p. 27, pl. 8, figs. 1–8; pl. 9, figs. 1–8; Licharew and Kotlyar, 1978, pl. 20, fig. 14; Shen et al., 2000, p. 742, figs. 10.24–10.32; Shen and Shi, 2009, p. 158, figs. 3Y–3CC; Tazawa and Shintani, 2015, p. 41, fig. 3.5.

Material.—One specimen from locality SSK27, external and internal moulds of a ventral valve, NU-B1867.

Remarks.—This specimen was described by Tazawa and Shintani (2015, p. 41, fig. 3.5) as *Echinauris opuntia* (Waagen, 1884) on account of its small, slightly transverse and rounded subtriangular ventral valve (length 11 mm, width 14 mm), with numerous long, thin spines on the lateral slopes. The type species, *Echinauris lateralis* Muir-Wood and Cooper (1960, p. 222, pl. 68, figs. 1–13), from the Word Formation of the Glass Mountains, Texas, differs from the present species in the larger size and in having stronger and thicker spines on the ventral valve.

Occurrence.—SK1 Unit.

Distribution. —Sakmarian–Changhsingian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), eastern Russia (South Primorye), central-southern China (Guangxi), southwestern China (Xizang), Pakistan (Salt Range) and Timor.

Echinauris sp.
(Figs. 20A, 32D–F)

Material.—Six specimens from locality SSK17: (1) external and internal moulds of two ventral valves, NU-B2287, 2288; (2) external and internal moulds of two dorsal valves, NU-B2289, 2290; and (3) external moulds of two dorsal valves, NU-B2291, 2292.

Remarks.—These specimens are safely assigned to the genus *Echinauris* MuirWood and Cooper, 1960 by the small, elongate shell (length 11 mm, width 15 mm in the best preserved dorsal valve specimen, NU-B2289), and the external ornaments of numerous stout spine bases on the ventral valve and numerous dimples and fine growth lines on the dorsal valve. The Nagaiwa–Sakamotozawa species is most like *Echinauris crassa* Cooper and Grant (1975, p. 1006, pl. 327, figs. 1–36), from the Leonardian of Texas, the USA, in the transverse outline and in having large ears, but differs from the latter in being wider configuration and larger size. *Echinauris interrupta* Cooper and Grant (1975, p. 1006, pl. 328, figs. 1–33), from the Wolfcampian of Texas, differs from the present species in the larger size and in having finer spine bases on the ventral valve. The type species, *Echinauris lateralis* Muir-Wood and Cooper (1960, p. 222, pl. 68, figs. 1–13), from the Word Formation of Texas, is readily distinguished from the present species in the less transverse outline and in having smaller ears. The Tashiroyama species may be a new species of *Echinauris*, although the specimens are poorly preserved.

Occurrence.—KN1 Unit.

Distribution.—Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakai Belt).

Superfamily PRODUCTOIDEA Gray, 1840
Family DICTYOCLOSTIDAE Stehli, 1954
Subfamily DICTYOCLOSTINAE Stehli, 1954
Genus *RETICULATIA* Muir-Wood and Cooper, 1960

Type species.—*Productus huecoensis* King, 1931.

Reticulatia cf. *donetziana* (Licharew, 1938)
(Fig. 19B, C)

Reticulatia cf. *donetziana* (Licharew, 1938). Tazawa and Shintani, 2015, p. 43, fig. 3.3, 3.4.

Material.—Two specimens from locality SSK27: (1) external and internal moulds of a dorsal valve, NU-B1873; and (2) external mould of a dorsal valve, NU-B1874.

Remarks.—These specimens were described by Tazawa and Shintani (2015, p. 43, fig. 3.3, 3.4) as *Reticulatia* cf. *donetziana* (Licharew, 1938). The Nagaiwa–Sakamotozawa species resembles *Reticulatia donetziana* (Licharew, 1938), from the Upper Carboniferous (Kasimovian) of the Donetz Basin, western Russia, in having a peculiar bordering flange at antero-lateral margins of the dorsal valve. The same ringlike structure has been described and figured by Sutton (1942, p. 464, pl. 71, figs. 12, 13) in the specimens of *Reticulatia americana* (Dunbar and Condra, 1932) from the Pennsylvanian

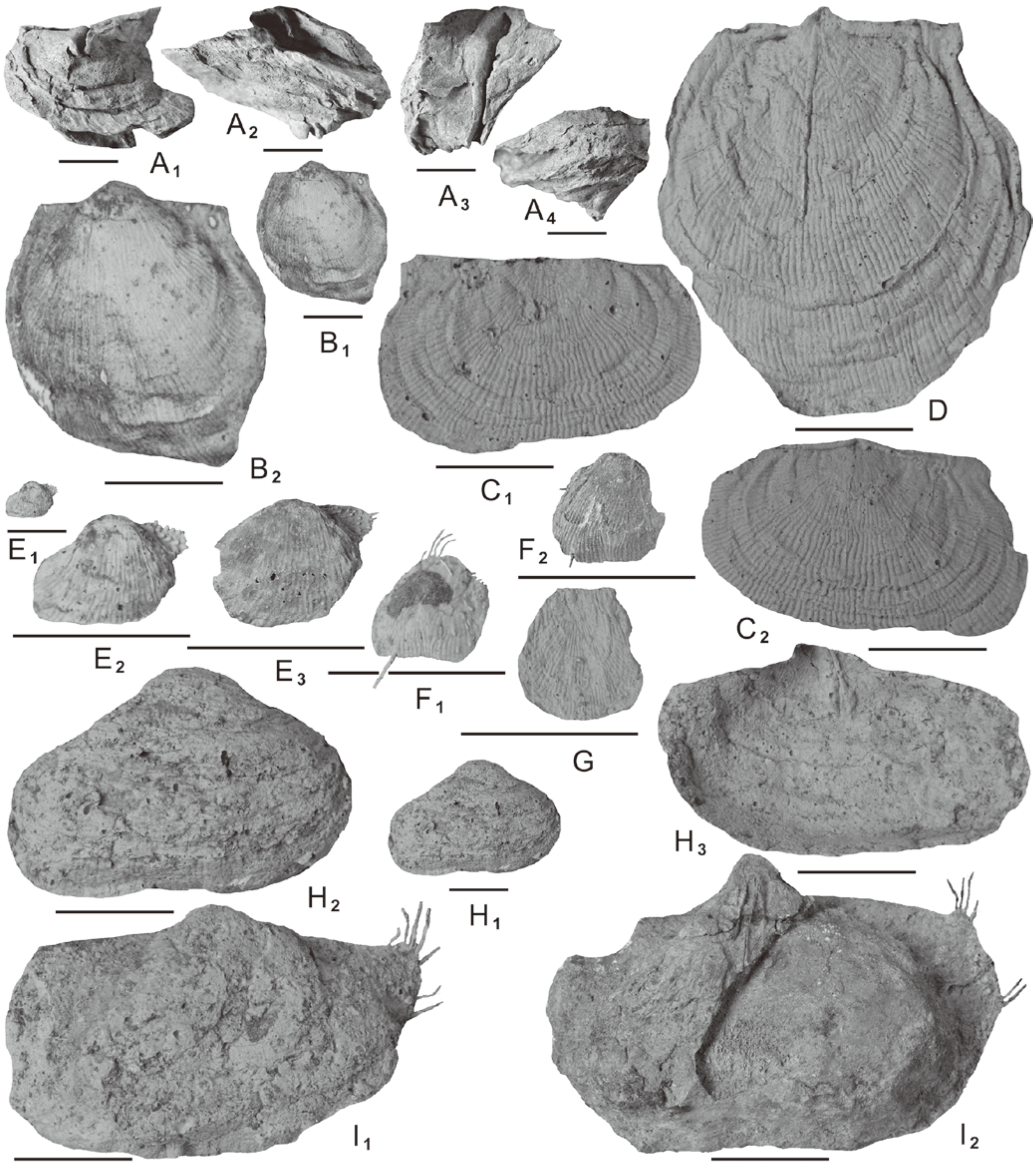

FIGURE 21. Brachiopods of the SK1 assemblage (4). **A,** *Scacchinella* sp., ventral (A_1), anterior (A_2), posterior (A_3) and lateral (A_4) views of internal mould of ventral valve, NU-B1286; **B–D,** *Linoproductus simensis* (Tschernyschew); B, external latex cast (B_1, B_2) of ventral valve, NU-B1875; C, external latex cast (C_1) and internal latex cast (C_2) of dorsal valve, NU-B1879; D, internal latex cast of dorsal valve, NU-B1881; **E–G,** *Auriculispina kanmerai* Tazawa and Shintani; E, external latex cast (E_1, E_2) and internal mould (E_3) of ventral valve, NU-B1882; F, external latex cast (F_1) and internal mould (F_2) of ventral valve, NU-B1884; G, external latex cast of dorsal valve, NU-B1893; **H, I,** *Terrakea* sp.; H, external latex cast (H_1, H_2) and internal latex cast (H_3) of ventral valve, NU-B1894; I, external latex cast (I_1) and internal mould (I_2) of ventral valve, NU-B1895. Scale bars are 1 cm.

of Illinois in the USA. The Kitakami species more like the Russian species than the American species in size, shape and external ornament of the dorsal valve. However, identification is difficult for the present material.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Superfamily ECHINOCONCHOIDEA Stehli, 1954
Family ECHINOCONCHIDAE Stehli, 1954
Subfamily ECHINOCONCHINAE Stehli, 1954
Genus *ECHINARIA* Muir-Wood and Cooper, 1960

Type species.—*Productus semipunctatus* Shepard, 1838.

Echinaria sp.
(Fig. 20A)

Echinaria sp. Tazawa and Shintani, 2015, p. 44, fig. 3.1.

Material.—One specimen from locality SSK27, external and internal moulds of a ventral valve, NU-B1899.

Remarks.—This specimen was described by Tazawa and Shintani (2015, p. 44, fig. 3.1) as *Echinaria* sp. on account of its large, elongate ventral valve (length more than 37 mm, width about 28 mm), with narrow and moderately deep sulcus, and ornamented by numerous broad concentric lamellae with 3–4 rows of spine bases on each lamella. The species identification is, however, difficult owing to the poorly preserved specimen.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Subfamily JURESANIINAE Muir-Wood and Cooper, 1960
Genus *JURESANIA* Fredericks, 1928

Type species.—*Productus juresanensis* Tschernyschew, 1902.

Juresania sp.
(Fig. 20B)

Juresania sp. Tazawa and Shintani, 2015, p. 45, fig. 3.2.

Material.—One specimen from locality SSK27, internal mould of a dorsal valve, NU-B1900.

Remarks.—The single dorsal valve specimen was previously described by Tazawa and Shintani (2015, p. 45, fig. 3.2) as *Juresania* sp. on account of its small size (length more than 24 mm, width 27 mm) and flat visceral disc, covered internally by numerous concentrically arranged endospines, and in having a long, thin breviseptum, short converging buttress plates enclosing end of breviseptum and the more posterior antron. The Nagaiwa–Sakamotozawa species somewhat resembles *Juresania juresanensis* (Tschernyschew, 1902, p. 276, 620, pl. 29, figs. 1, 2; pl. 47, figs. 1, 2; pl. 53, fig. 4), from the Cora Limestone of Timan, northern Russia and from the *Schwagerina* Limestone (Sakmarian) of the Urals, central Russia, in size and shape of the dorsal valve, but accurate comparison is difficult due to the poorly preserved specimen.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Family WAAGENOCONCHIDAE Muir-Wood and Cooper, 1960
Subfamily WAAGENOCONCHINAE Muir-Wood and Cooper, 1960
Genus *WAAGENOCONCHA* Chao, 1927

Type species.—*Productus humboldti* d'Orbigny, 1842.

Waagenoconcha humboldti (d'Orbigny, 1842)
(Fig. 20C, D)

Productus humboldti d'Orbigny, 1842, p. 54, pl. 5, figs. 4–7; Tschernyschew, 1902, p. 275, 620, pl. 53, figs. 1–3; Kozlowski, 1914, p. 40, pl. 7, figs. 7–9; Fredericks, 1925, p. 19, pl. 2, fig. 84.

Waagenoconcha humboldti (d'Orbigny). Chao, 1927, p. 86, pl. 15, figs. 2, 3; Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 98, pl. 15, fig. 109; Chronic, 1953, p. 86, pl. 15, figs. 4–7; Muir-Wood and Cooper, 1960, p. 252, pl. 89, figs. 6–10; Samtleben, 1971, p. 60, pl. 2, figs. 17–19; Ifanova, 1972, p. 102, pl. 3, figs. 11–13; Tazawa, 1974, p. 125, pl. 1, figs. 2, 3; pl. 2, fig. 1; pl. 4, fig. 6; Duan and Li, 1985, p. 108, pl. 35, figs. 2, 3; Minato et al., 1979a, pl. 65, figs. 3, 4; Wang and Zhang, 2003, p. 94, pl. 9, figs. 5–7; pl. 15, figs. 8–10; Tazawa and Shintani, 2010, p. 56, fig. 4.1–4.5; Tazawa and Shintani, 2015, p. 45, fig. 4.1.

Material.—Six specimens from locality SSK27: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, NU-B1281; (2) external mould of a ventral valve, NU-B1282; (3) external and internal moulds of a dorsal valve, NU-B1283; (4) external mould of a dorsal valve, with umbonal region of the opposite valve, NU-B1284; and (5) external moulds of two dorsal valves, NU-B1285, 1872.

Remarks.—These specimens were described by Tazawa and Shintani (2010, p. 56, fig. 4.1–4.5; 2015, p. 45, fig. 4.1) as *Waagenoconcha humboldti* (d'Orbigny, 1842) on account of size, shape and external ornament of both valves, especially the strong rugae on the ventral valve. *Waagenoconcha irginae* (Stuckenberg, 1898, p. 220, pl. 2, fig. 16), from the lower Permian (Asselian) of the Urals, is similar in general shape, but differs from *W*, *humboldti* in its larger size and finer spine bases on both ventral and dorsal valves.

Occurrence.—SK1 Unit.

Distribution.—Gzhelian–Capitanian: northeastern Japan (Nagaiwa – Sakamotozawa and Kamiyasse–Imo in the South

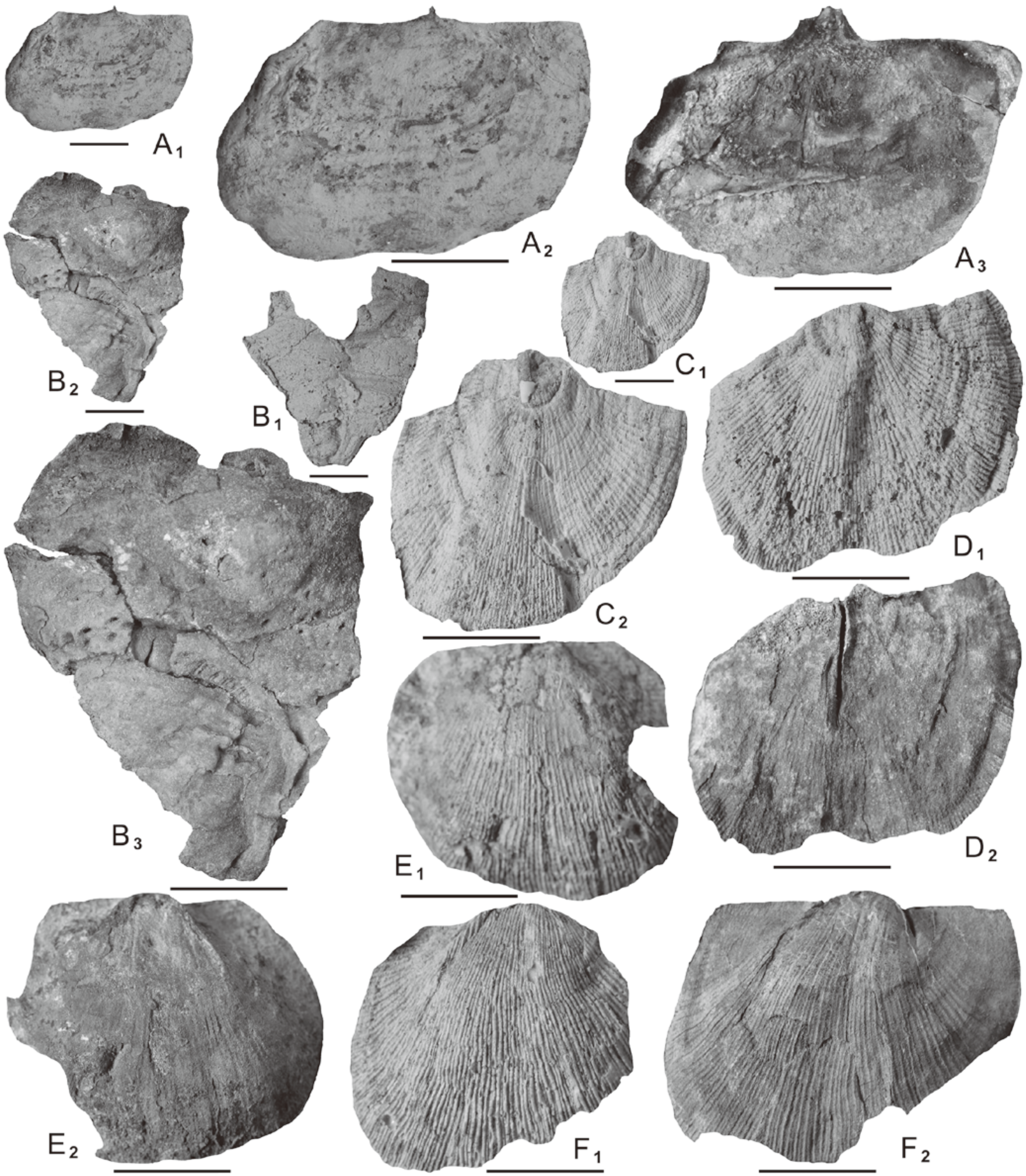

FIGURE 22. Brachiopods of the SK1 assemblage (5). **A,** *Terrakea* sp., external latex cast (A1, A2) and internal mould (A3) of dorsal valve, NU-B1897; **B,** *Cyclacantharia* sp., external latex cast (B1) and internal mould (B2, B3) of ventral valve, NU-B1870; **C–F,** *Derbyia crassa* (Meek and Hayden); C, external latex cast (C1, C2) of ventral valve, NUB1223; D, external latex cast (D1) and internal mould (D2) of ventral valve, NU-B1225; E, external latex cast (E1) and internal mould (E2) of dorsal valve, NU-B1232; F, external latex cast (F1) and internal mould (F2) of dorsal valve, NU-B1239. Scale bars are 1 cm.

Kitakami Belt), northern Russia (Timan, Pechora Basin and northern Urals), western Russia (Moscow Basin), northern China (Inner Mongolia), eastern Russia (South Primorye) and Bolivia.

Superfamily AULOSTEGOIDEA Muir-Wood and Cooper, 1960
Family ECHINOSTEGIDAE Muir-Wood and Cooper, 1960
Subfamily ECHINOSTEGINAE Muir-Wood and Cooper, 1960
Genus *EDRIOSTEGES* Muir-Wood and Cooper, 1960

Type species.—*Edriosteges multispinosus* Muir-Wood and Cooper, 1960.

Edriosteges cf. *multispinosus* Muir-Wood and Cooper, 1960
(Fig. 20E)

Edriosteges cf. *multispinosus* Muir-Wood and Cooper. Tazawa and Shintani, 2015, p. 47, fig. 4.2.

Material.—Two specimens from locality SSK28: (1) external and internal moulds of a ventral valve, NU-B1868; and (2) internal mould of a ventral valve, NU-B1869.

Remarks.—These specimens were described by Tazawa and Shintani (2015, p. 47, fig. 42) as *Edriosteges* cf. *multispinosus* Muir-Wood and Cooper, 1960. The Nagaiwa–Sakamotozawa species resembles well the type species, *Edriosteges multispinosus* Muir-Wood and Cooper, 1960, from the upper Leonard Formation of Texas, in the medium size (length 33 mm, width about 34 mm in the larger specimen, NU-B1868) and equidimensional subquadrate outline of the ventral valve, but accurate comparison is difficult owing to lack of the dorsal valve. *Edriosteges* sp. A, described by Tazawa and Araki (2014, p. 47, fig. 3.5) from the upper Permian (Changhsingian) Nabekoshiyama Formation of the Kesennuma area, South Kitakami Belt, differs from the present species in subtriangular outline of the ventral valve.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Subfamily AGELESIINAE Cooper and Grant, 1975
Genus *XENOSTEGES* Muir-Wood and Cooper, 1960

Type species.—*Xenosteges adherens* Muir-Wood and Cooper, 1960.

Xenosteges adherens Muir-Wood and Cooper, 1960
(Fig. 30G)

Xenosteges adherens Muir-Wood and Cooper, 1960, p. 112, pl. 10, figs. 1–13; Cooper and Grant, 1975, p. 855, pl. 232, figs. 1–48; pl. 233, fig. 40; pl. 234, figs. 28–32.

Material.—One specimen from locality SSK24, external mould of a dorsal valve, NU-B2321.

Remarks.—This specimen can be referred to *Xenosteges adherens* Muir-Wood and Cooper, 1960, redescribed by Cooper and Grant (1975, p. 855, pl. 232, figs. 1–48; pl. 233, fig. 40; pl. 234, figs. 28–32), from the Cathedral Mountain, Cibolo and Bone Spring Formations of Texas, by the medium-sized, transverse dorsal valve (length 10 mm, width 17 mm), having large ears and ornamented with irregular concentric lamellae. *Xenosteges magnus* Cooper and Grant (1975, p. 858, pl. 234, figs. 1–27), from the Road Canyon Formation of Texas, is also a large, transverse *Xenosteges* species, but differs from *X. adherens* in having low dorsal fold. *Xenosteges anomalus* Cooper and Grant (1975, p. 859, pl. 235, figs. 1–60; pl. 236, figs. 1–18), from the Cherry Canyon Formation of Texas, differs from the present species in having much smaller ears.

Occurrence.—SK4 Unit.

Distribution.—Sakmarian–Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt) and the USA (Texas).

Family SCACCHINELLIDAE Licharew, 1928
Subfamily SCACCHINELLINAE Licharew, 1928
Genus *SCACCHINELLA* Gemmellaro, 1891

Type species.—*Scacchinellsa variabilis* Gemmellaro, 1897.

Scacchinella sp.
(Fig. 21A)

Scacchinella sp. Tazawa and Shintani, 2010, p. 58, fig. 5.2.

Materilal.—One specimen from locality SSK27, external and internal moulds of a ventral valve, NU-B1286.

Remarks.—This specimen was previously described by Tazawa and Shintani (2010, p. 58, fig. 5.2) as *Scacchinella* sp. The ventral valve is large (length about 28 mm, width about 38 mm), conical shape, having a high and flat interarea which is both horizontally and longitudinally striated, and ornamented with strong irregular rugae and numerous fine spine bases on the anterolateral slopes. The Nagaiwa–Sakamotozawa species somewhat resembles *Scacchinella gigantea* Schellwien (1900b, p. 35, pl. 4, figs. 1–3; pl. 5, figs. 1–8, text-figs. 5, 6, 8) from the Trogkofel Formation (Sakmarian) of the Carnian Alps. The present material is, however, too imperfect for comparison.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Superfamily LINOPRODUCTOIDEA Stehli, 1954
Family LINOPRODUCTIDAE Stehli, 1954
Subfamily LINOPRODUCINAE Stehli, 1954
Genus *LINOPRODUCTUS* Chao, 1927

Type species.—*Productus cora* d'Orbigny, 1842.

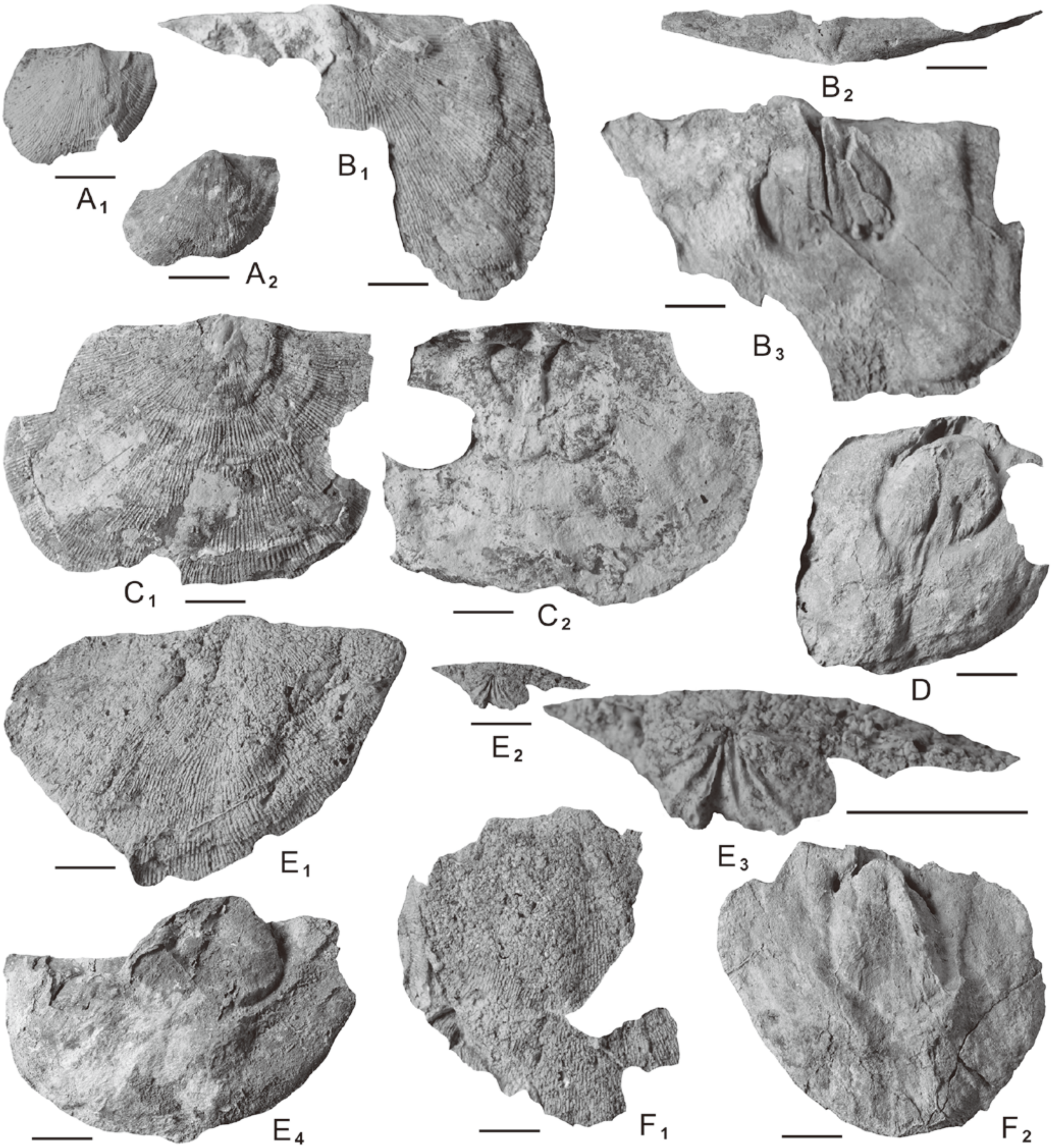

FIGURE 23. Brachiopods of the SK1 assemblage (6). **A,** *Derbyia crassa* (Meek and Hayden), external latex cast (A1) and internal mould (A2) of dorsal valve, NU-B1240; **B–F,** *Derbyia dorsosulcata* Liu and Waterhouse; B, ventral (B1) and posterior (B2) views of external latex cast and internal mould (B3) of ventral valve, NU-B1261; C, external latex cast (C1) and internal latex cast (C2) of ventral valve, NU-B1262; D, internal mould of dorsal valve, NU-B1272; E, ventral (E1) and posterior (E2, E3) views of external latex cast and internal mould (E4) of dorsal valve, NU-B1268; F, external latex cast (F1) and internal mould (F2) of dorsal valve, NU-B1269. Scale bars are 1 cm.

Linoproductus simensis (Tschernyschew, 1902)
(Fig. 21B–D)

Productus simensis Tschernyschew, 1902, p. 286, 626, pl. 35, fig. 7; pl. 55, figs. 2–5.
Linoproductus simensis (Tschernyschew). Volgin, 1960, p. 72, pl. 8, fig. 1; Zhao, 1965, p. 425, pl. 1, figs. 6, 7; Bamber and Waterhouse, 1971, pl. 16, figs. 8, 11; Sergunkova and Zhizhilo, 1975, p. 62, pl. 9, figs. 9, 10; pl. 10, figs. 8, 9; Lee and Gu, 1976, p. 258, pl. 139, figs. 9–12; Tong, 1978, p. 231, pl. 81, fig. 6; Kalashnikov, 1980, p. 47, pl. 10, figs. 8, 9 only; Lee et al., 1980, p. 376, pl. 152, fig. 11; Tazawa et al., 2001, p. 38, fig. 2D–J; Tazawa and Shintani, 2015, p. 48, fig. 4.3–4.5.
Linoproductus neimongolensis Lee and Gu, 1976, p. 258, pl. 178, figs. 1–10.

Material.—Seven specimens from locality SSK27: (1) external and internal moulds of two ventral valves, NU-B1875, 1876; (2) external and internal moulds of three dorsal valves, NU-B1877–1879; (3) external mould of a dorsal valve, NU-B1880; and (4) internal mould of a dorsal valve, NU-B1881.

Remarks.—These specimens were previously described by Tazawa and Shintani (2015, p. 48, figs. 4.3–4.5) as *Linoproductus simensis* (Tschernyschew, 1902) on account of its small size (length 37 mm, width 35 mm in the largest dorsal valve specimen, NU-B1881; length 25 mm, width 23 mm in the best preserved ventral valve specimen, NU-B1875), slightly elongate oval outline and external ornament consisting of numerous costellae and some rugae on the ventral valve. *Linoproductus neimongolensis* Lee and Gu (1976, p. 258, pl. 178, figs. 1–10), from the lower Permian of the Dongujimqinqi, Inner Mongolia, northern China, is deemed to be a junior synonym of *L. simensis*. The shells described by Chao (1927, p. 137, pl. 14, figs. 6–8) as *Linoproductus simensis* (Tschernyschew, 1902), from the Visean of Guizhou, southwestern China, differs from *L. simensis* in having stronger and fewer costellae. *Linoproductus hayasakai* Tazawa (1979, p. 26, pl. 4, figs. 5–11), from the lower Kamiyasse Formation (Wordian) of Wayama in the Kesennuma area, South Kitakami Belt, differs from *L. simensis* in its larger, transverse shell and in having stronger costellae on the ventral valve.

Occurrence.—SK1 Unit.

Distribution.—Bashkirian–Roadian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), northern Canada (northern Yukon Territory), northern Russia (northern Urals), central Russia (southern Urals), Uzbekistan (Fergana), northern China (Inner Mongolia) and southwestern China (Sichuan).

Genus *COSTATUMULUS* Waterhouse in Waterhouse and Briggs, 1986

Type species.—*Auriculispina tumida* Waterhouse in Waterhouse et al., 1983.

Costatumulus pseudotruncata (Ustritsky, 1960)
(Fig. 30D, E)

Cancrinella pseudotruncata Ustritsky, 1960, p. 36, pl. 6, figs. 10–12; pl. 7, figs. 1–3; Lee and Gu, 1976, p. 262, pl. 158, fig. 7; pl. 166, figs. 4, 7; Zhang et al., 1983, p. 296, pl. 130, figs. 13–16.
Costatumulus pseudotruncata (Ustritsky). Chen, 2004, p. 24, pl. 4, fig. 9; Chen and Shi, 2006, p. 159, pl. 12, figs. 13, 17–19; pl. 15, fig. 4.

Material.—Two specimens from locality SSK24, external and internal moulds of two ventral valves, NU-B2311, 2312.

Remarks.—These specimens are referred to *Costatumulus pseudotruncata* (Ustritsky, 1960, p. 36, pl. 6, figs. 10–12; pl. 7, figs. 1−3), from the upper Sakmarian–lower Artinskian of the western Kunlun Mountains, Xinjiang, northwestern China, in the medium size (length 19 mm, width 18 mm in the larger specimen, NU-B2311) and in having irregular rugae and fine numerous costellae (numbering 4–5 in 2 mm at about midlength) with quincuncially arranged elongate spine bases. The type species, *Costatumulus tumida* (Waterhuse in Waterhouse et al., 1983, p. 133, pl. 3, figs. 2–4, 6, 7), from the Tiverton Formation (Artinskian) of the north Bowen Basin, Queensland, eastern Australia, differs from *C. pseudotruncata* in the larger size and in having more elongate and sparsely arranged spine bases. *Costatumulus cancriniformis* (Tschernyschew, 1889, p. 283, 373, pl. 7, figs. 32, 33), from the Artinskian of the northern Urals, is distinguished from the present species by the strongly inflated ventral valve, which is ornamented with numerous undulated concentric rugae.

Occurrence.—SK4 Unit.

Distribution.—Sakmarian–Wordian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), northern China (Inner Mongolia) and northwestern China (Xinjiang).

Subfamily ANIDANTHINAE Waterhouse, 1968b
Genus *ANIDANTHUS* Hill, 1950

Type species.—*Linoproductus springsurensis* Booker, 1932.

Anidanthus sp.
(Fig. 32G, H)

Material.—Two specimens from locality SSK17, external moulds of two dorsal valves, NU-B2301, 2302.

Remarks.—These specimens are safely assigned to the genus *Anidanthus* Booker, 1932 on the basis of lamellose rugae on the visceral disc of the dorsal valve and large, prominent ears with rugae on the valve. *Anidanthus boikowi* (Stepanov, 1946), redescribed by Grigorjeva and Kotlyar (in Sarytcheva, 1977, p. 57, pl. 5, figs. 4–13), from the lower Permian of the Verkhoyansk Range, northern Russia, somewhat resembles the

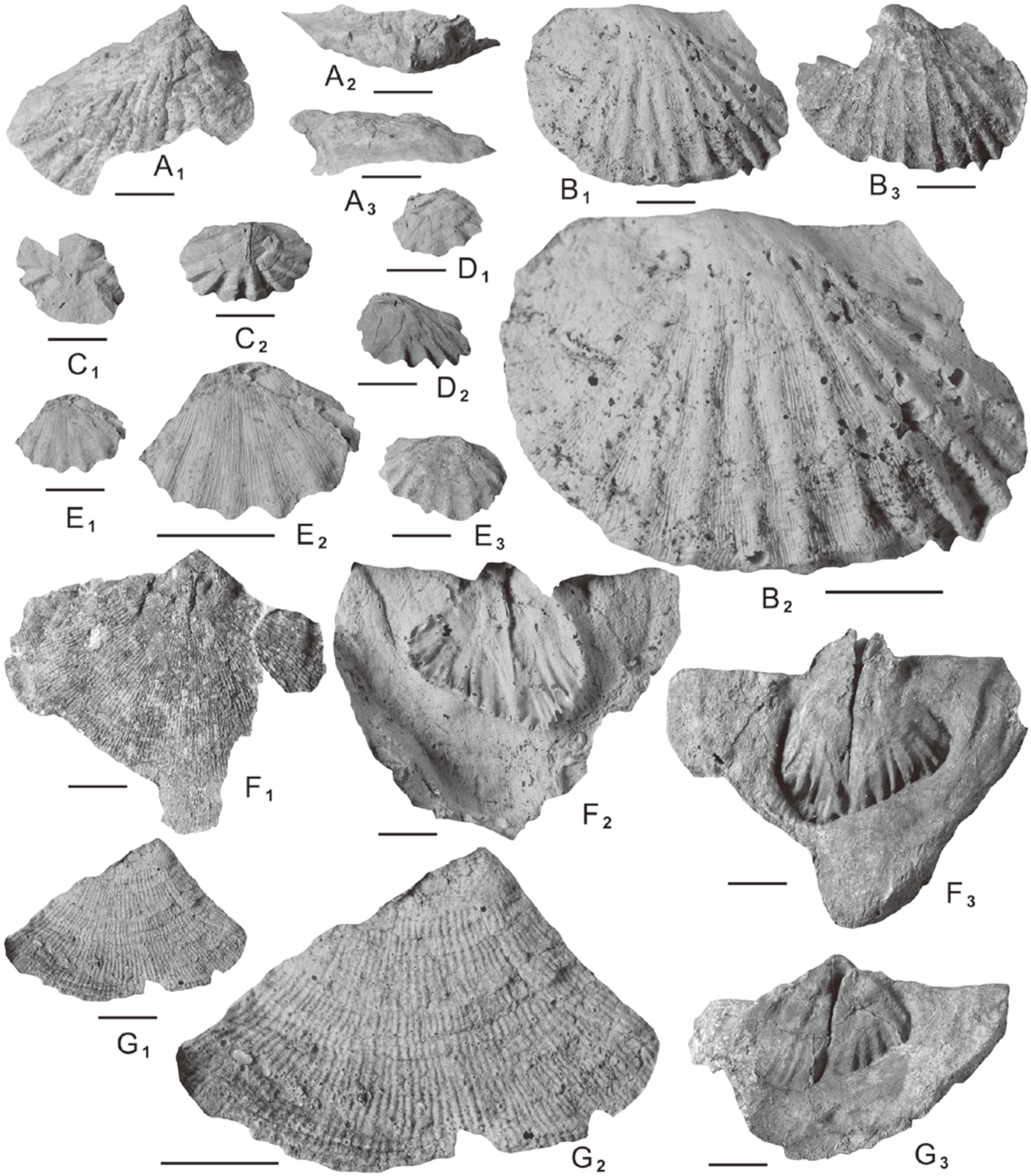

FIGURE 24. Brachiopods of the SK1 assemblage (7). **A, B,** *Meekella striatocostata* (Cox); A, ventral (A1), posterior (A2) and lateral (A3) views of external latex cast of ventral valve, NU-B1212; B, external latex cast (B1, B2) and internal mould (B3) of dorsal valve, NU-B1213; **C–E,** *Meekella depressa* Schellwien; C, external latex cast (C1) and internal mould (C2) of ventral valve, NU-B2379: D, external latex cast (D1) and internal mould (D2) of ventral valve, NU-B2380; E, external latex cast (E1, E2) and internal mould (E3) of dorsal valve, NU-B2881; **F, G,** *Derbyia sakamotozawensis* Shintani; F, external latex cast (F1), internal latex cast (F2) and internal mould (F3) of ventral valve, NU-B1273; G, external latex cast (G1, G2) and internal mould (G3) of ventral valve, NU-B1274. Scale bars are 1 cm.

Kitakami species in having large ears but differs in the larger and less transverse dorsal valve. The type species, *Anidanthus springsurensis* (Booker, 1932, p. 67, pl. 3, figs. 1–6; pl. 4, figs. 1–7), from the lower Bowen Series of Queensland, eastern Australia, differs from the present species in being less transverse outline. The Kitakami species is probably a new species, although the material is poorly preserved and not adequate for the establishment.

Occurrence.—KN1 Unit.

Distribution.—Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Family KANSUELLIDAE Muir-Wood and Cooper, 1960
Subfamily AURICULISPININAE Waterhouse in Waterhouse and Briggs, 1986
Genus *AURICURLISPINA* Waterhouse, 1975

Type species.—*Cancrinella levis* Maxwell. 1964.

Auriculispina kanmerai Tazawa and Shintani, 2015
(Figs. 21E–G, 30F)

Auriculispina kanmerai Tazawa and Shintani, 2015, p. 49, fig. 5.1–5.3.

Material.—Thirteen specimens from locality SSK24 and SSK27: (1) external and internal moulds of five ventral valves, NU-B1882 (holotype), NU-B1883–1886; (2) external mould of a ventral valve, NU-B2322; (3) internal moulds of three ventral valves, NU-B1887–1889; (4) external and internal moulds of two dorsal valves, NU-B1890, 1891; and (4) external mould of two dorsal valves, NU-B1892, 1893.

Remarks.—These specimens were described by Tazawa and Shintani (2015, p. 49, figs. 5.1–5.3) as *Auriculispina kanmerai* Tazawa and Shintani, 2015. This species is small in size (length 7 mm, width about 9 mm in the holotype, NU-B1882) for the genus and transversely subquadrate in outline, and most resembles *Auriculispina capillata* (Waterhouse, 1988, p. 156, fig. 8), from the Grant Formation (Asselian–Sakmarian) of the Canning Basin, western Australia, in size and shape of the shell, but differs from the Australian species in having finer capillae on the ventral valve. The type species, *Auriculispina levis* (Maxwell, 1964, p. 34, pl. 6, figs. 15–18), from the upper Carboniferous–lower Permian (Sakmarian) of the Yarrol Basin, eastern Australia, is readily distinguished from *A. kanmerai* by the larger and more transverse shell and in having coarser capillae on the ventral valve.

Occurrence.—SK1 and SK4 units.

Distribution.—Sakmarian–Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Subfamily PAUCISPINAURIINAE Waterhouse in Waterhouse and Briggs, 1986
Genus *TERRAKEA* Booker, 1930

Type species.—*Productus brachythaerus* Morris in de Strezelecki, 1845.

Terrakea sp.
(Figs. 21H, I, 22A)

Terrakea sp. Tazawa and Shintani, 2015, p. 51, figs. 5.4–5.6.

Material.—Five specimens from localities SSK14 and SSK28: (1) external and internal moulds of two ventral valves, NU-B1894, 1895; (2) internal mould of a ventral valve, NU-B1896; and (3) external and internal moulds of two dorsal valves, NU-B1897, 1898.

Remarks.—These specimens were described by Tazawa and Shintani (2015, p. 51, fig. 5.4–5.6) as *Terrakea* sp. The Nagaiwa–Sakamotozawa species is a large, transverse species (length 28 mm, width 38 mm in the largest specimen, NU-B1895), and somewhat resembles the type species, *Terrakea brachythaera* (Morris in de Strezelecki, 1845), redescribed and refigured by Briggs (1998, p. 176, fig. 87A–I), from the Broughton Formation of the Sydney Basin, eastern Australia, in outer configuration, but accurate comparison is difficult due to the ill-preserved specimens. *Terrakea nabekoshiyamensis* Tazawa (2012, p. 26, fig. 4.13, 4.14), from the upper Permian (Changhsingian) Nabekoshiyama Formation of the Kesennuma area, South Kitakami Belt, is also transverse in outline, but it differs from the present species by the much smaller dimensions.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Superfamily RICHTHOFENIOIDEA Waagen, 1885
Family TEGULIFERINIDAE Muir-Wood and Cooper, 1960
Subfamily CYCLACANTHARIINAE Cooper and Grant, 1975
Genus *CYCLACANTHARIA* Cooper and Grant, 1969

Type species.—*Cyclacantharia kingorum* Cooper and Grant, 1969.

Cyclacantharia sp.
(Fig. 22B)

Cyclacantharia sp. Tazawa and Shintani, 2015, p. 52, figs. 5.7, 5.8.

Material.—Two specimens from locality SSK14: (1) external and internal moulds of a ventral valve, NU-B1870; and (2) internal mould of a ventral valve, NU-B1871.

Remarks.—These specimens were described by Tazawa and Shintani (2015, p. 52, fig. 5.7, 5.8) as *Cyclacantharia* sp. on account of the highly cone-shaped ventral valve (height about 40 mm in the larger specimen, NU-B1870), without a median septum and with numerous strong spine bases, all around the inside of the cup aperture. The Nagaiwa–Sakamotozawa species resembles the type species, *Cyclacantharia kingorum* Cooper

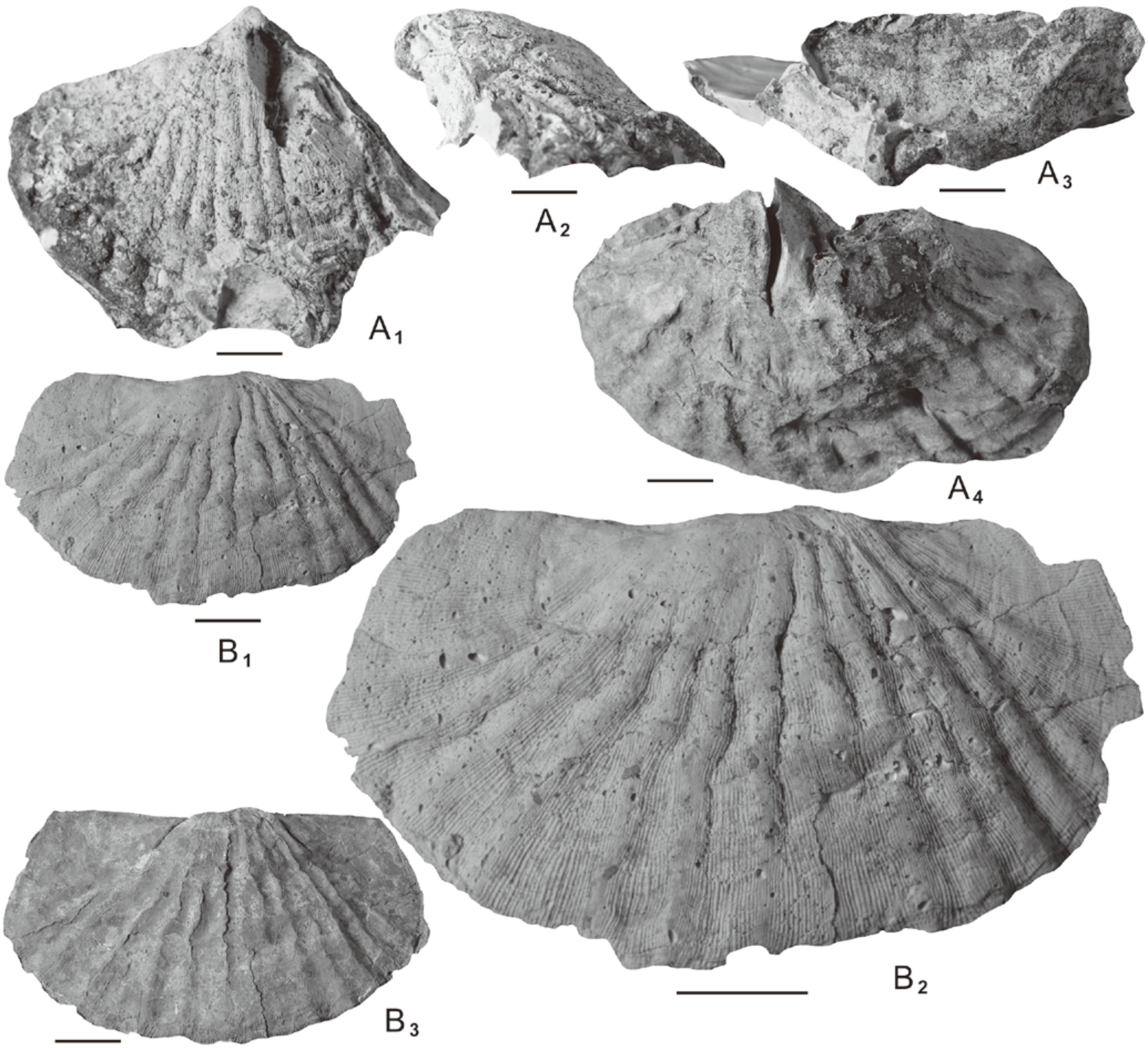

FIGURE 25. Brachiopods of the SK1 assemblage (8). **A, B,** *Meekella nagaiwensis* Shintani; A, ventral (A1), lateral (A2) and posterior (A3) views of external latex cast of ventral valve, NU-B1216; B, external latex cast (B1, B2) and internal mould (B3) of dorsal valve, NU-B1217. Scale bars are 1 cm.

and Grant (1969, p. 7, pl. 5, figs. 13–16), from the Word Formation of Texas, in size and shape of the ventral valve. However, accurate comparison is difficult because of ill preservation of the present material.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Suborder LYTTONIIDINA Williams, Harper and Grant, 2000
Superfamily LYTTONIOIDEA Waagen, 1883

Family LYTTONIIDAE Waagen, 1883
Subfamily POIKILOSAKINAE Williams, 1953
Genus *PSEUDOLEPTODUS* Stehli, 1956

Type species.—*Pseudoleptodus getawayensis* Stehli, 1956.

Pseudoleptodus sp.
(Fig. 32J, K)

Material.—Two specimens from locality SSK17: (1) external and internal moulds of a ventral valve, NU-B2299; and (2) internal mould of a ventral valve, NU-B2300.

Remarks.—These specimens can be assigned to the genus *Pseudoleptodus* Stehli, 1956 in having regularly arranged, low and wide lateral septa, with flattened top. The Nagaiwa–Sakamotozawa species is probably an advanced-form of the genus, and somewhat resembles *Pseudoleptodus getawayensis* Stehli (1956), redescribed by Cooper and Grant (1974, p. 395, pl. 130, figs. 18–34) from the Cherry Canyon Formation of the Guadalupe Mountains, Texas, in size and shape of the shell. But the Texan species differs from the present species in having lateral septa extending anteriorly at steeper angle to the median septum.

Occurrence.—KN1 Unit.

Distribution.—Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Superfamily PERMIANELLOIDEA He and Zhu, 1979
Family PERMIANELLIDAE He and Zhu, 1979
Genus *DICYSTOCONCHA* Termier and Termier in Termier et al., 1974

Type species.—*Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974.

Dicystoconcha lapparenti Termier and Termier in Termier et al., 1974
(Fig. 32I)

Dicystoconcha lapparenti Termier and Termier in Termier et al., 1974, p. 123, pl. 22, figs. 1, 2, text-fig. 22; Wang and Jin, 1991, p. 495, pl. 1, figs. 1–9; pl. 3, figs. 1–7; Shen and Tazawa, 2014, p. 248, fig. 3.1–3.5; Tazawa et al., 2014, p. 383, fig. 2.6; Tazawa, 2015, p. 73, fig. 6.6; Tazawa and Araki, 2018, p. 16, fig. 4.2 .
Dipunctella contricta Liang in Wang et al., 1982, p. 229, pl. 102, fig. 3.
Guangjiayanella guangjiayanensis Yang, 1984, p. 212, pl. 31, figs. 11–16, text-fig. 5.9.
Guangdongina xiamaoensis Mou and Liu, 1989, p. 458, pl. 1, figs. 1–9; pl. 2, figs. 1– 7; text-fig. 5.
Guandongina leguminiformis Mou and Liu, 1989, p. 458, pl. 3, figs. 4–6.
Guangdongina perforates Mou and Liu, 1989, p. 459, pl. 2, fig. 8; pl. 3, figs. 1–3.
Guangdongina sp. Mou and Liu, 1989, p. 459, pl. 2, fig. 9.
Peritisteges latesulcata Liang, 1990, p. 380, pl. 42, figs. 1, 2.
Fabulasteges planata Liang, 1990, p. 381, pl. 42, figs. 3, 4.

Material.—One specimen from locality SSK17, internal mould of a ventral valve, NU-B2280.

Remarks. —The single specimen from the lower part of the Kanokura Formation (KN1 Unit) in the Nagaiwa–Sakamotozawa area is referred to *Dicystoconcha lapparenti* Termier and Termier (in Termier et al., 1974, p. 123, pl. 22, figs. 1, 2, text-fig. 22), from the lower Murgabian of Wardak, central Afghanistan, in the small, ovate and bilobate ventral valve (length more than 11 mm, width about 13 mm), with a shallow incision and a distinct central platform. As discussed by Shen and Tazawa (2014, p. 248), the following six species from the Kungurian–Capitanian of South China are junior synonyms of *Dicystoconcha lapparenti*: *Guangjiayanella guangjiayanensis* Yang, 1984, *Guangdongina xiamaoensis* Mou and Liu, 1989, *G. leguminiformis* Mou and Liu, 1989, *G. perforatus* Mou and Liu, 1989, *Guangdongina* sp. Mou and Liu, 1989 and *Fabulasteges planata* Liang, 1990. Moreover, *Paritisteges latesulcata* Liang (1990, p. 380, pl. 42, figs. 1, 2), from the Wordian of Zhejiang, eastern China, is also considered to be a junior synonym of the present species.

Occurrence.—KN1 Unit.

Distribution.—Kungurian–Wuchiapingian: northeastern Japan (Nagaiwa–Sakamotozawa, Kamiyasse–Imo and Hitachi in the South Kitakami Belt), Afghanistan, northern China (Inner Mongolia), eastern China (Zhejiang) and central-southern China (Hubei and Guangdong).

Order ORTHOTETIDA Waagen, 1884
Suborder ORTHOTETIDINA Waagen, 1884
Superfamily ORTHOTETOIDEA Waagen, 1884
Family DERBYIIDAE Stehli, 1954
Genus *DERBYIA* Waagen, 1884

Type species.—*Derbyia regularis* Waagen, 1884.

Derbyia crassa (Meek and Hayden, 1858)
(Figs. 22C–F, 23A)

Orthisina crasa Meek and Hayden, 1858, p. 261.
Derbyia crassa (Meek and Hayden). Girty, 1915, p. 54, pl. 7, fig. 1; Kelly, 1930, p. 138, pl. 11, fig. 4; Sayre, 1930, p. 93, pl. 4, figs. 3–5; Dunbar and Condra, 1932, p. 79, pl. 3, figs. 1–12, text-fig. 3; Hoare, 1961, p. 27, pl. 1, figs. 17–23; Sturgeon and Hoare, 1968, p. 26, pl. 3, figs. 1–4; Sutherland and Harlow, 1973, p. 21, pl. 2, figs. 8–12; Brew and Beus, 1976, p. 894, pl. 1, figs. 14–18; Shintani, 2011, p. 81, figs. 4.4–4.8, 5.1–5.3.
Derbyia sp. C. Nakamura, 1972, p. 401, pl. 8, figs. 2, 4–6.
Derbyia sp. Minato et al., 1979a, pl. 46, figs. 7, 8; Tazawa and Nakamura, 2015, p. 167, fig. 7.11–7.13.
Derbyia buchi (d'Orbigny). Tazawa and Shintani, 2014, p. 21, fig. 3.5, 3.6.

Material.—Forty specimens from localities SSK14 and SSK28; (1) external and internal moulds of two conjoined shells, NU-B1221, 1222; (2) external and internal moulds of seven ventral valves, NU-B1223–1229; (3) internal moulds of two ventral valves, NU-B1230, 1231; (4) external and internal moulds of twenty dorsal valves, NU-B1232–1251; (5) external moulds of two dorsal valves, NU-B1252, 1253; and (6) internal moulds of seven dorsal valves, NU-B1254–1260.

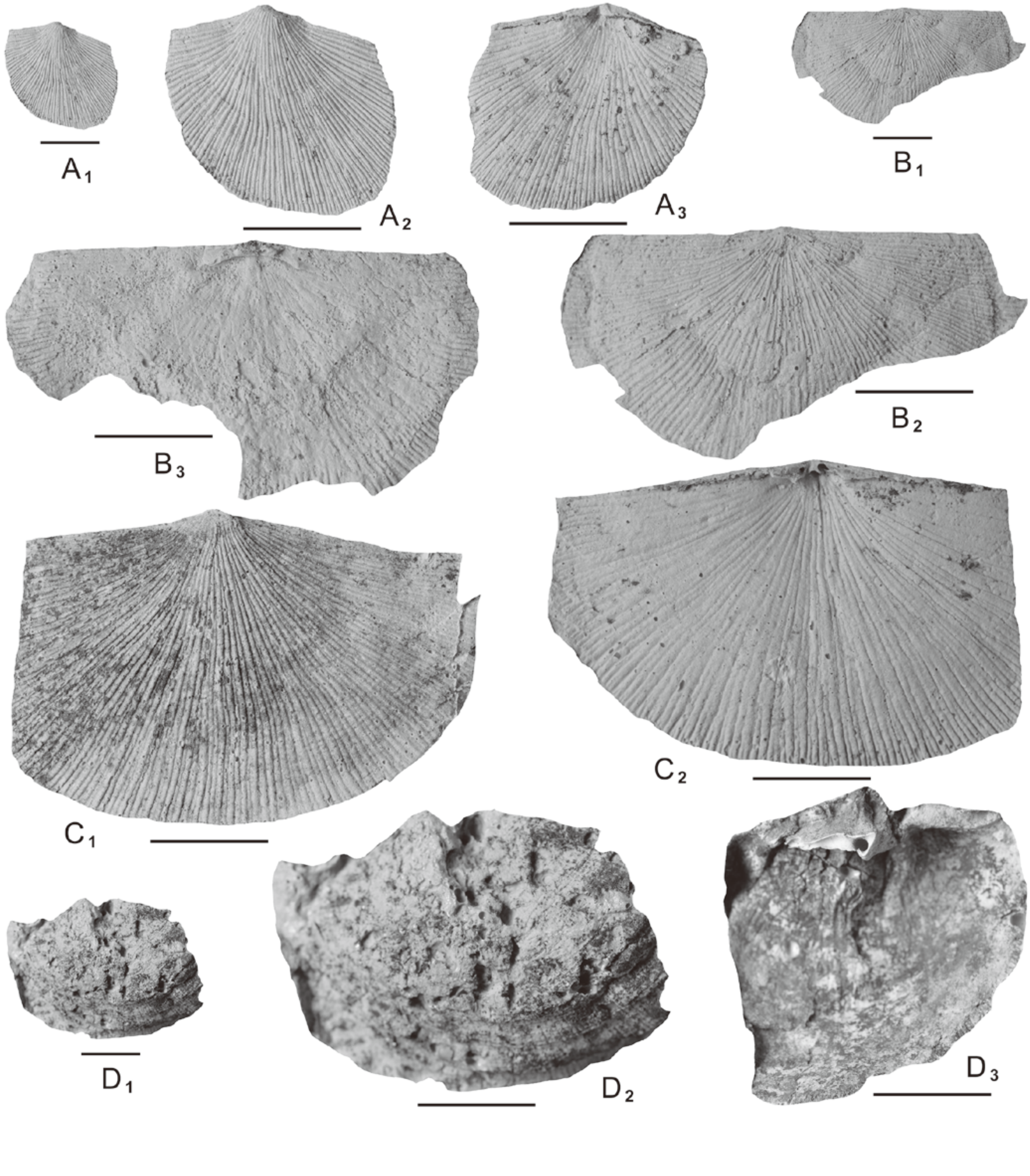

FIGURE 26. Brachiopods of the SK1 assemblage (9). **A,** *Schuchertella cooperi* Grant, external latex cast (A1, A2) and internal latex cast (A3) of ventral valve, NU-B2433; **B, C,** *Schuchertella* sp., B, external latex cast (B1, B2) and internal latex cast (B3) of ventral valve, NU-B2436; C, external latex cast (C1) and internal latex cast (C2) of dorsal valve, NU-B2437; **D,** *Streptorhynchus sibiricus* Zavodowsky, external latex cast (D1, D2) and internal latex cast (D3) of dorsal valve, NU-B2434. Scale bars are 1 cm.

Remarks.—The specimens from Nagaiwa–Sakamotozawa were previously described by Shintani (2011, p. 81, figs. 4.4–4.8, 5.1–5.3) as *Derbyia crassa* (Meek and Hayden, 1858) on account of the small size (length 24 mm, width 26 mm in the average- sized ventral valve specimen, NU-B1221), subquadrate outline, and in having a low interarea, and ornamented with numerous fine costellae (25–28 in 10 mm at midlength). Two species, *Derbyia* sp. C Nakamura, 1972 and *Derbyia* sp. Minato et al., 1979a, both from the Hosoo Formation (Kungurian) of Nakadaira in the South Kitakami Belt, are assigned to the present species. *Derbyia buchi* (d'Orbigny, 1842), redescribed by Kozlowski (1914, p. 57, pl. 8, figs. 1–6) from the upper Carboniferous of Bolivia, resembles *D. crassa*, but differs in its larger size and in having coarser costellae on the ventral and dorsal valves.

Occurrence.—SK1 Unit.

Distribution.—Moscovian–Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa, Nakadaira and Kamiyasse in the South Kitakami Belt) and the USA (Michigan, Ohio, Missouri, Nebraska, Kansas, Oklahoma, New Mexico and Arizona).

Derbyia dorsosulcata Liu and Waterhouse, 1985
(Fig. 23B–F)

Magniderbyia sp. Nakamura, 1972, p. 403, pl. 9, fig. 2.
Derbyia dorsosulcata Liu and Waterhouse, 1985, p. 11, pl. 1, figs. 1, 7, 8, 10; Wang and Zhang, 2003, p. 121, pl. 25, figs. 1, 2; pl. 26, figs. 2–6; Shintani, 2011, p. 84, figs. 5.4–5.6, 6.1–6.4; Tazawa and Shintani, 2014, p. 21, fig. 3.8.

Material.—Twelve specimens from localities SSK14 and SSK28: (1) external and internal moulds of four ventral valves, NU-B1261–1264; (2) external mould of a ventral valve, NU-B1265; (3) internal moulds of two ventral valves, NU-B1266, 1267; (4) external and internal moulds of four dorsal valves, NU-B1268–1271; and (5) internal mould of a dorsal valve, NU-B1272.

Remarks.—These specimens were described by Shintani (2011, p. 84, figs. 5.1–5.6, 6.1–6.4) as *Derbyia dorsosulcata* Liu and Waterhouse, 1985 on account of the large (length 44 mm, width 64 mm in the best preserved ventral valve specimen, NU-B1261), subrectangular shell, with a low, transversely subtriangular interarea and moderately deep dorsal sulcus, the external ornament consisting of a few rugae and numerous costellae with broad interspaces, and the large muscle scars in the ventral valve. Comparison with the other *Derbyia* species is fully discussed by Shintani (2011, p. 86).

Occurrence.—SK1 Unit.

Distribution.—Sakmarian–Wordian: northeastern Japan (Nagaiwa–Sakamotozawa and Kamiyasse in the South Kitakami Belt) and northern China (Inner Mongolia).

Derbyia sakamotozawensis Shintani, 2011
(Fig. 24F, G)

Derbyia sakamotozawensis Shintani, 2011, p. 86, fig. 7.1–7.4.

Material.—Seven specimens from locality SSK14: (1) external and internal moulds of four ventral valves, NU-B1273 (holotype), 1274–1276; (2) internal moulds of two ventral valves, NU-B1277, 1278; and (3) internal mould of a dorsal valve, NU-B1279.

Remarks.—*Derbyia sakamotozawensis* Shintani, 2011, from the lower part (SK1 Unit) of the Sakamotozawa Formation in Nagaiwa–Sakamotozawa, is large, semicircular species (length 49 mm, width 61 mm in the holotype, NU-B1273), with external ornament consisting of numerous fine costellae (17–20 in 10 mm at about midlength of ventral valve), and a large muscle scar in the ventral valve. *Derbyia wabaunsensis* Dunbar and Condra (1932, p. 95, pl. 7, figs. 1–6), from the Wabaunsee Group of Nebraska in the USA, is similar to *D. sakamotozawensis* in size and outline of the shell, but the American species differs from the Nagaiwa–Sakamotozawa species in having strongly concave ventral valve and smaller ventral muscle scar. The preceding species, *Derbyia dorsosulcata* Liu and Waterhouse, differs from *D. sakamotozawensis* in the subrectangular outline and in having smaller muscle scar in the ventral valve.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Family MEEKELLIDAE Stehli, 1954
Subfamily MEEKELLINAE Stehli, 1954
Genus *MEEKELLA* White and St. John, 1867

Type species.—*Plicatula striatocostata* Cox, 1857.

Meekella striatocostata (Cox, 1857)
(Fig. 24A, B)

Plicatula striatocostata Cox, 1857, p. 568, pl. 8, fig. 7.
Meekella striatocostata (Cox). Tschernyschew, 1902, p. 211, 582, pl. 24, figs. 7, 8; pl. 26, fig. 4; pl. 51, fig. 3; Girty, 1909, p. 54, pl. 6, fig. 6; Hamlet, 1928, p. 9, pl. 1, fig. 5; Dunbar and Condra, 1932, p. 125, pl. 16, figs. 1–10; pl. 17, fig. 3; Sturgeon and Hoare, 1968, p. 24, pl. 2, figs. 1–3; West, 1977, p. 741, text-fig. 3; Li (Lee) et al., 1986, p. 218, pl. 1, fig. 6; Shintani, 2011, p. 77, fig. 3.1–3.3.
Meekella cf. *striatocostata* (Cox). Nakamura, 1972, p. 385, pl. 5, fig. 1; Minato et al., 1979a, pl. 59, figs. 3, 4.
Meekella cf. *striatocostata* (Cox). Sutherland and Harlow, 1973, p. 20, pl. 1, fig. 18.

Material.—Six specimens from localities SSK14, SSK27 and SSK28: (1) external and internal moulds of a ventral valve, NU-B2377; (2) external mould of a ventral valve, NU-B1212; (3) external and internal moulds of two dorsal valves, NU-B1213, 1214; (4) internal mould of a ventral valve, NU-B2378; and (5) external mould of a dorsal valve,

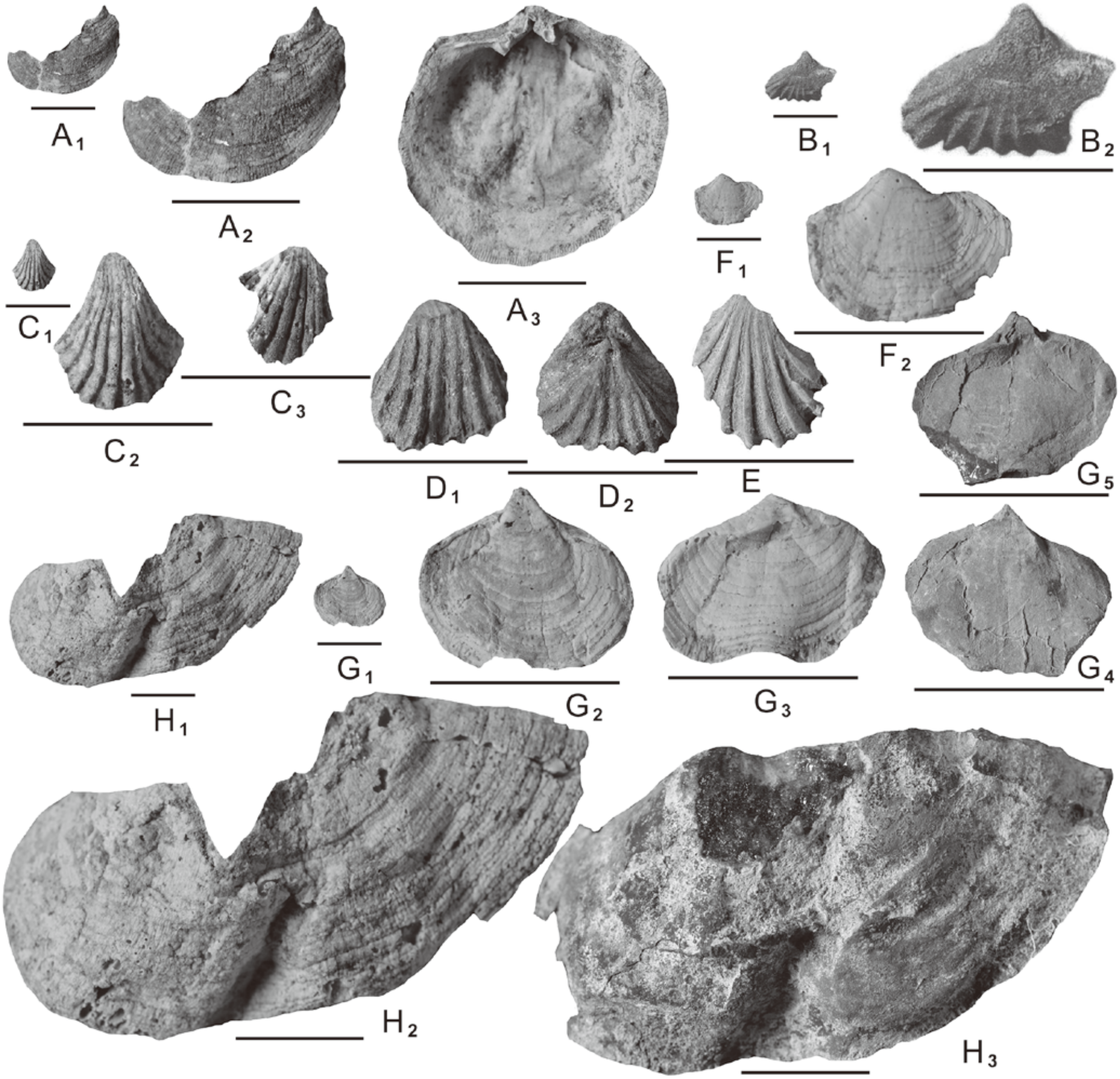

FIGURE 27. Brachiopods of the SK1 assemblage (10). **A,** *Streptorhynchus* sp., external latex cast (A_1, A_2) and internal latex cast (A_3) of dorsal valve, NU-B2435; **B,** *Rhynchopora* sp., internal mould (B_1, B_2) of ventral valve, NU-B1280; **C–E,** *Hustedia ratburiensis* Waterhouse and Piyasin; C, ventral (C_1, C_2) and dorsal (C_3) views of external latex cast of conjoined shell, NU-B2371; D, ventral (D_1) and dorsal (D_2) views of internal mould of conjoined shell, NU-B2374; E, internal mould of dorsal valve, NU-B2376; **F, G,** *Squamularia asiatica* Chao; F, external latex cast (F_1, F_2) of ventral valve, NU-B2429; G, ventral (G_1, G_2) and dorsal (G_3) views of external latex cast, and ventral (G_4) and dorsal (G_5) views of internal mould of conjoined shell, NU-B2424; **H,** *Pinegathyris royssiana* (von Keyserling), external latex cast (H_1, H_2) and internal mould (H_3) of ventral valve, NU-B2285. Scale bars are 1 cm.

NU-B1215.

Remarks.—Most of the specimens from Nagaiwa–Sakamotozawa were previously described by Shintani (2011, p. 77, fig. 3.1–3.3) as *Meekella striatocostata* (Cox, 1857). This species is medium in size for the genus (length 29 mm, width 42 mm in the best preserved and average-sized dorsal valve specimen, NU-B1213), subtriangular in outline, with the greatest width near midlength of ventral valve; external surface of both valves are ornamented with regular, rounded costae and fine costellae, numbering 13–14 costae and 15–17 costellae in 5 mm at midlength. *Meekella skenoides* Girty (1908, p. 206, pl. 30, figs. 8, 9), from the Delaware Mountain Formation of Texas, is similar in size and trigonal outline, but differs in having more strongly convex ventral valve and rather angular costae. *Meekella eximia* (von Eichwald, 1840, p. 157, pl.17, figs. 4–8), from the Kasimovian of Kasimov, western Russia, differs from *M. striatocostata* in having less convex ventral valve with flat interarea.

Occurrence.—SK1 Unit.

Distribution.—Bashkirian–Wuchiapingian: northeastern Japan (Nagaiwa–Sakamotozawa and Imo in the South Kitakami Belt), the USA (Ohio, Kentucky, Iowa, Missouri, Nebraska, Kansas and New Mexico), central Russia (southern Urals), central-southern China (Guangxi) and Indonesia (Timor).

Meekella depressa Schellwien, 1900b
(Fig. 24C–E)

Meekella depressa Schellwien, 1900b, p. 23, pl. 3, figs. 3, 4; Gauri, 1965, p. 74, pl. 10, fig. 8; Ramovs, 1965, pl. 15, fig. 4.

Material.—Three specimens from locality SSK27: (1) external and internal moulds of two ventral valves, NU-B2379, 2380; and (2) external and internal moulds of a dorsal valve, NU-B2381.

Description.—Shell small in size for genus, transversely subrectangular in outline, hinge long but shorter than the greatest width at about midlength; length 15 mm, width 25 mm in the largest specimen (NU-B2379). Ventral valve moderately convex in lateral and anterior profiles; sulcus absent. Dorsal valve gently convex in both lateral and anterior profiles; no fold. External surface of both valves ornamented with costae and numerous fine costellae; costae occur anterior one third of valve, numbering 7–8 on both valves; costellae rounded, numbering 8–9 in 2 mm at about midlength of dorsal valve. Ventral interior with long, subparallel dental plates. Dorsal interior with a pair of long, widely divergent socket plates. Other internal structures of both valves not well preserved.

Remarks.—These specimens can be referred to *Meekella depressa* Schellwien (1900b, p. 23, pl. 3, figs. 3, 4), from the Trogkofel Formation of the Carnian Alps, Austria, in the small size, transverse outline and in having costae on anterior one third of both ventral and dorsal valves. *Meekella bisculpta* Grant (1976, p. 58, pl. 10, figs. 1–35), from the Ratburi Formation of Ko Muk, southern Thailand, is also characterized by the costae beginning relatively far forward, but the Thailand species differs from *M. depressa* in being less transverse outline.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), Austria and Slovenia.

Meekella nagaiwensis Shintani, 2011
(Fig. 25A, B)

Meekella nagaiwensis Shintani, 2011, p. 79, figs. 3.4–3.5, 4.1–4.3.

Material.—Seven specimens from localities SSK14, SSK27 and SSK28; (1) external and internal moulds of a ventral valve, NU-B1216 (holotype); (2) external and internal moulds of two dorsal valves, NU-B1217, 1218; (3) internal mould of a ventral valve, NU-B2382; (4) external mould of two dorsal valves, NU-B1219, 2383; and (5) internal mould of a dorsal valve, NU-B1220.

Remarks.—*Meekella nagaiwensis* Shintani, 2011 was described by Shintani (2011, p. 79, figs. 3.4–3.5, 4.1–4.3) from the lower part (SK1 Unit) of the Sakamotozawa Formation in Nagaiwa–Sakamotozawa, South Kitakami Belt. This species is large (length 58 mm, width 82 mm in the largest specimen, NU-B1216), transverse *Meekella*, having strongly convex ventral valve and slightly convex to nearly flat dorsal valve, and ornamented with somewhat irregular costae and fine numerous costellae (14–16 in 5 mm at midlength) on both valves. *Meekella kueichowensis* Huang (1933, p. 27, pl. 3, figs. 19–21; pl. 4, figs. 1–4), from the Lungtan Formation of Guizhou, southwestern China, resembles *M. nagaiwensis* in the large size, but differs from the latter in the less transverse outline and in having more regular costae on the both valves. *Meekella grandis* King (1931, p. 54, pl. 6, figs. 5–7), from the Leonard Formation of Texas, is also a large-sized species, but differs from *M. nagaiwensis* in the less transverse outline and in having coarser costellae. *Meekella gigantea* Hayasaka (1933, p. 26, pl. 6, fig. 2; pl. 9, figs. 3, 4; pl. 10, figs. a, b; pl. 11, figs. a, b; pl. 12, fig. 1, text-fig. 4) from the Nabeyama Formation (Kungurian) of Kuzu, central Japan, is readily distinguished from the present species by the larger size and much coarser costae on both valves.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa−Sakamotozawa in the South Kitakami Belt).

Family SCHUCHERTELLIDAE Williams, 1953
Subfamily SCHUCHERTELLINAE Williams, 1953
Genus *SCHUCHERTELLA* Girty, 1904

Type species.—*Streptorhynchus lens* White, 1862.

Schuchertella cooperi Grant, 1976
(Fig. 26A)

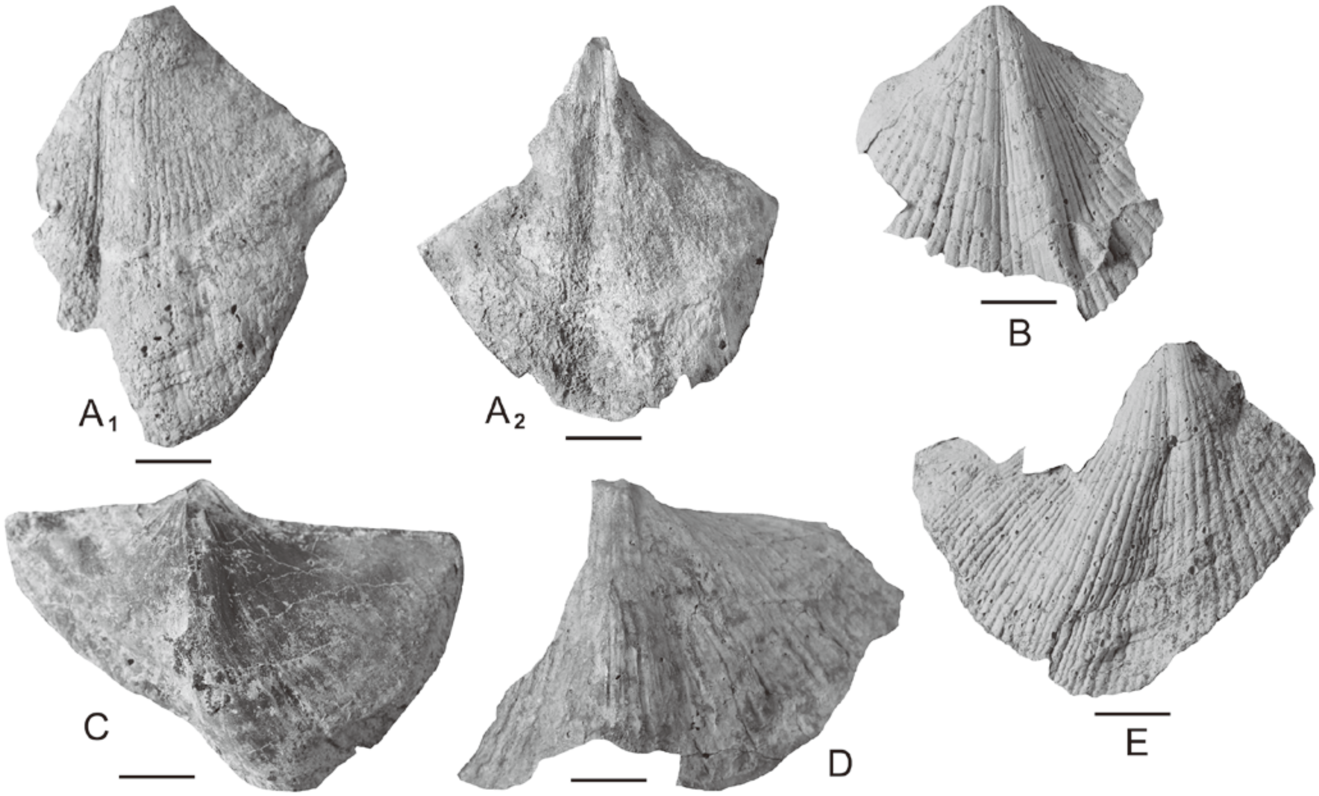

FIGURE 28. Brachiopods of the SK1 assemblage (11). **A–E,** *Choristites* sp.; A, external latex cast (A1) and internal mould (A2) of ventral valve, NU-B2386; B, external latex cast of ventral valve, NU-2387; C, internal mould of dorsal valve, NU-B2390; D, internal mould of dorsal valve, NU-B2391; E, external latex cast of ventral valve, NU-B2388. Scale bars are 1 cm.

Schuchertella cooperi Grant, 1976, p. 42, pl. 4, figs. 1–42; pl. 6, figs. 1–12.

Material.—One specimen from locality SSK27, external and internal moulds of a ventral valve, NU-B2433.

Remarks.—This specimen can be referred to *Schuchertella cooperi* Grant (1976, p. 42, pl. 4, figs. 1–42; pl. 6, figs. 1–12), from the Ratburi Formation of Ko Muk, southern Thailand, in the medium size (length 20 mm, width 21 mm), semicircular, flattened ventral valve, externally ornamented with numerous costellae (numbering 12–14 in 5 mm at about midlength) and several irregular concentric lamellae, and the interior with no median septum. *Schuchertella semiplana* (Waagen, 1884, p. 608, pl. 55, figs. 1, 2), from the Chhidru Formation of the Salt Range, Pakistan, differs from *Schuchertella cooperi* in the slightly larger size and in having coarser costellae on the ventral valve. *Schuchertella debaisiensis* Wang and Zhang (2003, p. 122, pl. 27, figs. 1–9; pl. 29, figs. 1, 2), from the Dashizhai and Zhesi Formations of Inner Mongolia, northern China, differs from the present species in the larger size and more transverse outline.

Occurrence.—SK1 Unit

Distribution.—Sakmarian − Kungurian: northeastern Japan (Nagaiwa − Sakamotozawa in the South Kitakami Belt) and southern Thailand (Ko Muk).

Schuchertella sp.
(Fig. 26B, C)

Material.—Two specimens from locality SSK27: (1) external and internal moulds of a ventral valve, NU-B2436; and (2) external and internal moulds of a dorsal valve, NU-B2437.

Description.—Shell large in size for genus, transversely subrectangular in outline, hinge slightly shorter than greatest width at about midlength; length 23 mm, width about 38 mm in the ventral valve specimen (NU-B2436); length 28 mm, width about 43 mm in the dorsal valve specimen (NU-B2437). Dorsal valve nearly flat, ornamented with numerous costellae, numbering 9–10 in 5 mm at about midlength. Dorsal interior with a pair of strong socket ridges and a short, thin median ridge. Muscle scar not well preserved.

Remarks.—These specimens are safely assigned to the genus *Schuchertella* Girty, 1904 by the presence of median ridge in the dorsal valve. The Nagaiwa–Sakamotozawa species resembles *Schuchertella bassa* Grant (1995, p. 658, fig. 4.1–4.16), from the upper Permian (Dorashamian) of Hydra Island, Greece, in size and shape of the dorsal valve, but differs from the Greek species in having more regular and slightly coarser costellae. The preceding species, *Schuchertella cooperi* Grant, is readily distinguished from the present species in much smaller size and less transverse outline. The present species may be a new species, although the material is inadequate for establishment.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotoawa in the South Kitakami Belt).

Subfamily STREPTORHYNCHINAE Stehli, 1954
Genus *STREPTORHYNCHUS* King, 1850

Type species.—*Terebratulites pelargonatus* von Schlotheim, 1816.

Streptorhynchus sibiricus Zavodowsky, 1968
(Fig. 26D)

Streptorhynchus sibiricus Zavodowsky, 1968, p. 89, pl. 32, fig. 13; Zavodowsky and Stepanov, 1970, p. 73, pl. 1, figs. 6, 7.

Material.—One specimen from locality SSK14, external and internal moulds of a dorsal valve, NU-B2434.

Remarks.—The single specimen from Nagaiwa–Sakamotozawa is lacking the ventral valve, but can be referred to *Streptorhynchus sibiricus* Zavodowsky (1968, p. 89, pl. 32, fig. 13), from the lower Permian (Asselian) of the Kolyma Basin, northern Russia, in the medium size (length 31 mm, width about 32 mm), moderately convex dorsal valve, ornamented with numerous costellae (numbering 11–12 in 5 mm near anterior margin of the valve) and irregularly developed strong concentric rugae, and the internal structure, consisting of strong socket plates and large cardinal process. *Streptorhynchus kayseri* Schellwien, 1900a, redescribed by Grabau (1931, p. 241, pl. 24, fig. 1) from the Zhesi Formation of Zhesi, Inner Mongolia, northern China, differs from *S. sibiricus* in the much transverse dorsal valve. The type species, *Streptorhynchus pelargonatus* von Schlotheim, 1816, redescribed by Waagen (1884, p. 579, pl. 50, figs. 3–5, 7), from the Wargal Formation of the Salt Range, Pakistan, is readily distinguished from the present species in being much smaller size.

Occurrence.—SK1 Unit.

Distribution.—Asselian–Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt) and northern Russia (Kolyma).

Streptorhynchus sp.
(Fig. 27A)

Material.—One specimen from locality SSK27, external and internal moulds of a dorsal valve, NU-B2435.

Remarks.—This specimen is safely assigned to the genus *Streptorhynchus* King, 1850 by the medium-sized (length about 22 mm, width about 22 mm), subcircular and moderately convex dorsal valve, which is externally ornamented with numerous fine costellae (18–19 in 5 mm near the anterior margin of the valve) and irregular strong concentric rugae, and internally provided with prominent muscle scars and large cardinal process. The Nagaiwa–Sakamotozawa species most resembles *Streptorhynchus zhesiensis* Duan and Li (1985, p. 105, 202, pl. 32, figs. 7, 8), from the Yihewusu Formation of Inner Mongolia, northern China, in size, shape and external ornament of the dorsal valve. But accurate comparison is difficult owing to lack of the ventral valve. *Streptorhynchus khwaense* Grant (1976, p. 49, pl. 7, figs. 1–41), from the Ratburi Formation of Ban Kao and Khao Phrik, southern Thailand, differs from the present species in having slightly irregular and stronger costellae on the dorsal valve. The preceding species, *Streptorhynchus sibiricus* Zavodowsky, 1968, is distinguished from the present species in the larger size and in having coarser costellae on the dorsal valve.

Occurrence.—SK1 Unit.

Distribution.—Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt) .

Order RHYNCHONELLIDA Kuhn, 1949
Superfamily STENOSCISMATOIDEA Oehlert, 1887
Family STENOSCISMATIDAE Oehlert, 1887
Subfamily STENOSCISMATINAE Oehlert, 1887
Genus *STENOSCISMA* Conrad, 1839

Type species.—*Terebratula schlottheimii* von Buch, 1834.

Stenoscisma sp.
(Fig. 32L)

Material.—One specimen from locality SSK17, external and internal moulds of a ventral valve, NU-B2306.

Remarks.—This specimen is safely assigned to the genus *Stenoscisma* Conrad, 1839 by the rhynchonellid-formed shell, with a spondylium in the ventral valve. The Nagaiwa–Sakamotozawa species is medium in size (length 15 mm, width 27 mm), transversely subtrigonal in shape, and external surface of the ventral valve is ornamented with strong costae, numbering 4 on sulcus and 5 on each flank. *Stenoscisma hueconianum* (Girty, 1929), redescribed by Cooper and Grant (1976a, p. 2096, pl. 563, figs. 1–54), from the upper Wolfcampian of Texas, resembles the present species in shape and external ornament of the ventral valve, but differs from the latter in the much smaller size. *Stenoscisma mutabilis* (Tschernyschew, 1902, p. 81, 491, pl. 22, fig. 18; pl. 23, fig. 10; pl. 45, figs. 1–15; pl. 46, fig. 14), from the *Schwagerina* Horizon of the Urals and Timan, resembles the present species in size, shape and external ornament of the ventral valve, particularly in

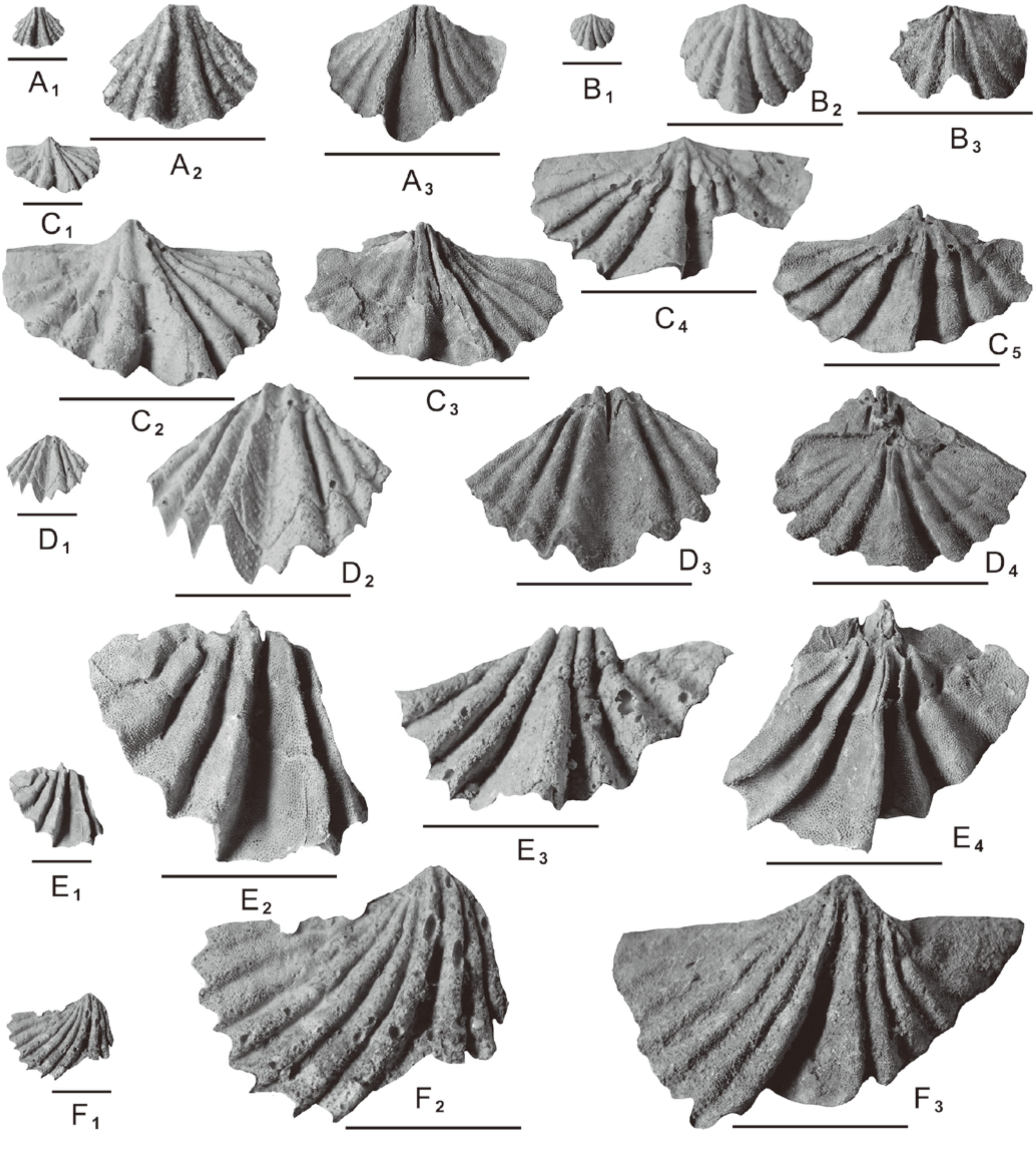

FIGURE 29. Brachiopods of the SK1 assemblage (12). **A, B,** *Callispirina ornata* (Waagen); A, external latex cast (A_1, A_2) and internal mould (A_3) of ventral valve, NU-B2392; B, external latex cast (B_1, B_2) and internal mould (B_3) of dorsal valve, NU-B2393; **C–F,** *Spiriferellina cristata* (von Schlotheim); C, ventral (C_1, C_2) and dorsal (C_4) views of external latex cast, and ventral (C_3) and dorsal (C_5) views of internal mould of conjoined shell, NU-B2394; D, ventral view (D_1, D_2) of external latex cast, and ventral (D_3) and dorsal (D_4) views of internal mould of conjoined shell, NU-B2395; E, ventral (E_1, E_2) and dorsal (E_4) views of internal mould, and dorsal view (E_3) of external latex cast of conjoined shell, NU-B2396; F, external latex cast (F_1, F_2) and internal mould (F_3) of ventral valve, NU-B2400. Scale bars are 1 cm.

the medium-sized, transversely subtrigonal specimen (illustrated by Tschernyschew, 1902, pl. 45, fig. 14). However, an accurate comparison is difficult for this poorly preserved specimen.

Occurrence.—KN1 Unit.

Distribution.—Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Superfamily RHYNCHOPOROIDEA Muir-Wood, 1955
Family RHYNCHOPORIDAE Muir-Wood, 1955
Subfamily RHYNCHOPORINAE Muir-Wood, 1955
Genus *RHYNCHOPORA* King, 1865

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

Rhynchopora sp.
(Fig. 27B)

Rhynchopora sp. Tazawa and Shintani, 2010, p. 58, fig. 5.1.

Material.—Two spcimens from localities SSK5 and SSK28: (1) external and internal moulds of a ventral valve, NU-B2432; and (2) internal mould of a ventral valve, NU-B1280.

Remarks.—One of the specimens (NU-B1280) was previously described by Tazawa and Shintani (2010, p. 58, fig. 5.1) as *Rhynchopora* sp. The ventral valve is small in size for the genus (length about 8 mm, width about 12 mm), transversely subpentagonal in outline, having a broad and deep sulcus, ornamented with simple costae numbering 5 on sulcus and 4 on each lateral slope, and possessing thin, short dental plates in the valve. The Nagaiwa–Sakamotozawa species resembles *Rhynchopora tschernyshae* Koczyrkevicz (1979, p. 47, pl. 11, figs. 1–4, text-fig. 4) from the lower Barabaschevka Formation (Wordian) of South Primorye, eastern Russia in size, shape and external ornament of the ventral valve. However, the single imperfect specimen does not allow specific assignment.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Superfamily RHYNCHOTETRADOIDEA Licharew, 1956
Family RHYNCHOTETRADIDAE Licharew, 1956
Subfamily RHYNCHOTETRADINAE Licharew, 1956
Genus *TRASGU* Martinez Chacon, 1979

Type species.—*Trasgu minor* Martinez Chacon, 1979.

Trasgu confinensis (Schellwien, 1892)
(Fig. 31E, F)

Rhynchonella confinensis Schellwien, 1892, p. 54, pl. 8, figs. 11, 12; Schellwien, 1900b, p. 93, pl. 14, figs. 8–10.

Material.—Four specimens from locality SSK24: (1) external and internal moulds of two ventral valves, NU-B2307, 2308; and (2) internal mould of two ventral valves, NU-B2309, 2310

Description.—Shell large in size for genus, subtriangular in outline, widest at two-thirds length from umbo; length 23 mm, width 22 mm in the largest specimen (NU-B2307). Ventral valve gently and unevenly convex in lateral profile, strongly convex at umbo, gently convex to almost flattened at broad venter, and strongly convex near anterior margin; sulcus wide and shallow on anterior half of valve. Dorsal valve moderately convex, with wide and low fold. External surface of ventral valve ornamented with strong costae, occurring near antero-lateral margins, numbering five on each lateral flank. Interior of ventral valve, distinct spondylium with median septum in posterior portion. Interior of dorsal vale not well preserved.

Remarks.—These specimens are referred to *Trasgu confinensis* (Schellwien, 1892), originally described by Schellwien (1892, p. 54, pl. 8, figs. 11, 12) as *Rhynchonella confinensis* Schellwien, 1892, from the Trogkofel Formation of the Karavanke Mountains, Slovenia, in the large size. The type species, *Trasgu minor* Martinez Chacon (1979, p. 252, pl. 30, figs. 8–23, text-fig. 13), from the lower Bashkirian of the Cantabrica Mountains, northern Spain, differs from *T. confidensis* in the much smaller size.

Occurrence.—SK4 Unit.

Distribution.—Sakmarian–Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt) and Slovenia (Karavanke Mountains).

Order ATHYRIDIDA Boucot, Johnson and Staton, 1964
Suborder ATHYRYDIDINA Boucot, Johnson and Staton, 1964
Superfamily ATHYRIDOIDEA Davidson, 1881
Family ATHYRIDIDAE Davidson, 1881
Subfamily CLEIOTHYRIDININAE Alvarez, Rong and Boucot, 1998
Genus *PINEGATHYRIS* Grunt, 1980

Type species.—*Terebratula royssiana* von Keyserling, 1846.

Pinegathyris royssiana (von Keyserling, 1846)
(Figs. 27H)

Terebratula royssiana von Keyserling, 1846, p. 237.
Athyris (*Cliothyris*) *royssiana* (von Keyserling). Tschernyschew, 1902, p. 103, 511, pl. 43, figs. 11, 12.
Athyris royssiana (von Keyserling). Netschajew, 1911, p. 93, 153, pl. 13, figs. 1–7.
Athyris royssiana Tschernyschew. Wiman, 1914, p. 30, pl. 1, figs. 21–55; pl. 2, figs. 1–13; Frebold. 1950, p. 69, pl. 6, figs. 6, 7.
Cleiothyris royssiana aberr. *typica* Netschaew. Fredericks, 1934, p. 23, pl. 5, figs. 1–10.
Athyris (*Cleiothyridina*) *royssiana* (von Keyserling). Stepanov, 1937, p. 156, 181, pl. 9, figs. 8–10.
Cleiothyridina royssiana (von Keyserling). Gobbett, 1963, p. 161, pl. 21, figs. 13–16; pl. 22, figs. 1, 2; Grigorjeva, 1967, pl. 8, figs. 1–3; Stepanov et al., 1975, pl. 3, figs. 20, 21.

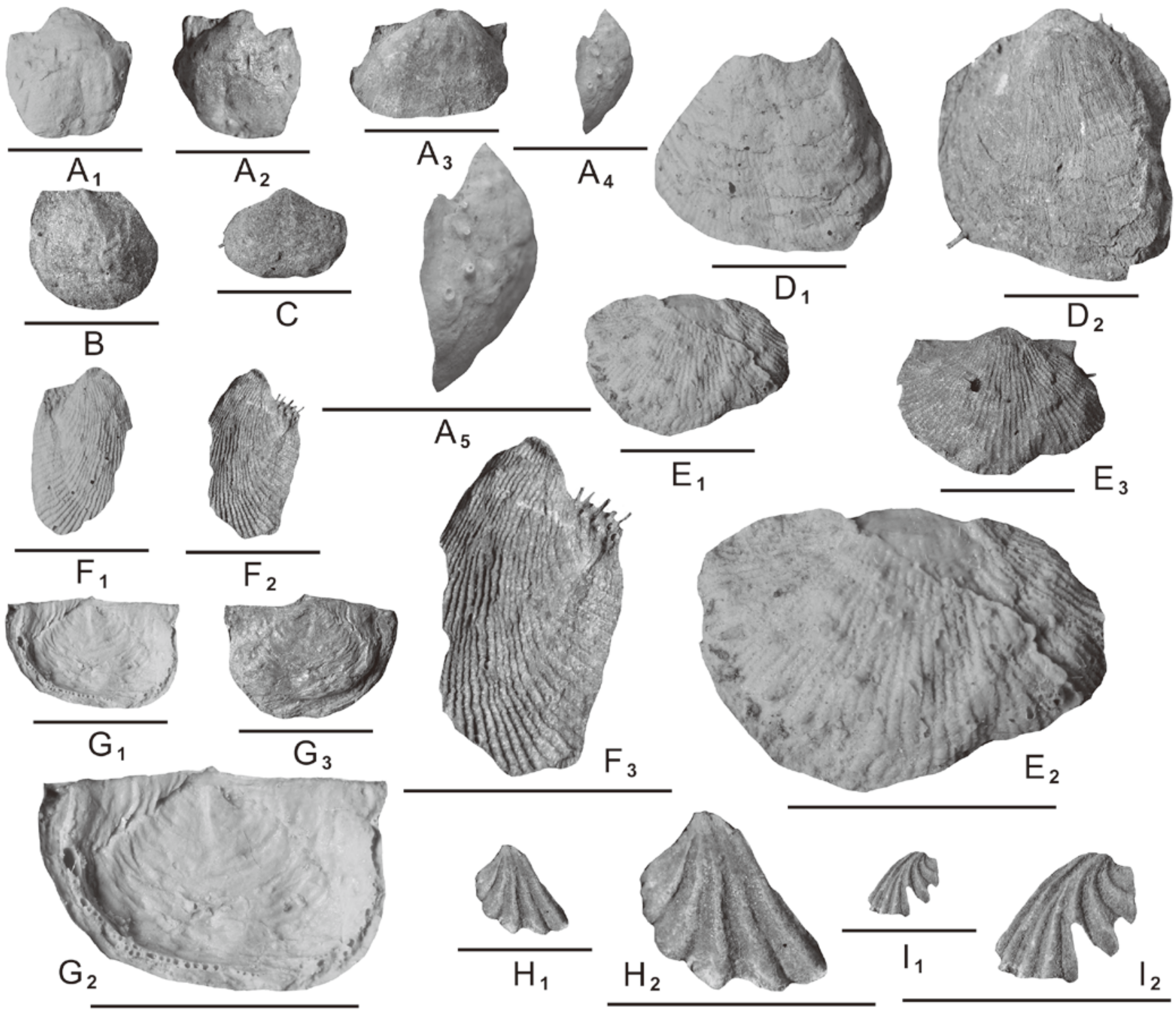

FIGURE 30. Brachiopods of the SK4 assemblage (1). **A–C,** *Anemonaria kitakamiense* sp. nov.; A, external latex cast (A1), external mould (A2), internal mould (A3) and lateral view of external latex cast A4) of ventral valve, NU-B2325 (holotype); B, internal mould of ventral valve, NU-B2326; C, internal mould of ventral valve, NU-B2329; **D, E,** *Costatumulus pseudotruncata* (Ustritsky); D, external latex cast (D1) and internal mould (D2) of ventral valve, NU-B2311; E, external latex cast (E1, E2), and internal mould (E3) of ventral valve, NU-B2312; **F,** *Auriculispina kanmerai* Tazawa and Shintani, external latex cast (F1) and external mould (F2, F3) of ventral valve, NU-B2322; **G,** *Xenosteges adherens* Muir-Wood and Cooper, external latex cast (G1, G2) and internal mould (G3) of dorsal valve, NU-B2321; **H, I,** *Hustedia ratburiensis* Waterhouse and Piyasin; H, internal mould (H1, H2) of dorsal valve, NU-B2323; I, internal mould (I1, I2) of dorsal valve, NU-B2324. Scale bars are 1 cm.

Pinegathyris royssiana roysiana (von Keyserling). Grunt, 1980, p. 91, pl. 10, figs. 1–7; pl. 11, figs. 1, 2, text-figs. 44–46; Kalashnikov, 1986, pl. 130, figs. 1, 2.

Pinegathyris royssiana (von Keyserling). Grunt, 2006, p. 166, pl. 17, figs. 4, 8.

Material.—One specimen from locality SSK14, external and internal moulds of a ventral valve, NU-B2385.

Remarks.—This specimen can be referred to *Pinegathyris royssiana* (von Keyserling, 1846), redescribed by Grunt (2006, p. 166, pl. 17, figs. 4, 8) from the upper Kazanian of the Kanin Peninsula, northern Russia, in the large, transverse ventral valve (length about 25 mm, width about 50 mm), with a narrow and deep sulcus, and external ornament consisting of growth lamellae bearing numerous flat spines (numbering 5–6 in 2 mm at about midlength of the ventral valve). *Pinegathyris alata* (Grunt, 1980, p. 92, pl. 10, fig. 8), from the Kazanian of Pinega, northern Russia, differs from *P. royssiana* in its more transverse outline.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian–Wordian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), northern Russia (Kanin Peninsula, Pinega and Timan), Greenland, Svalbard (Spitsbergen), and central Russia (southern Urals).

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 ratburiensis Waterhouse and Piyasin, 1970
(Figs. 27C–E, 30H, I, 33A, B)

Hustedia ratburiensis Waterhouse and Piyasin, 1970, p. 138, pl. 23, figs. 15–30; Grant, 1976, p. 241, pl. 66, figs. 1–69: pl. 67, figs. 51–58; Yanagida and Nakornsri, 1999, p. 118, pl. 32, figs. 11–16; Archbold, 1999, figs. 5E–H; Tazawa, 2001, p. 299, fig. 8.6; Tazawa, 2008b, p. 53, fig. 8.2–8.6; Tazawa in Tazawa et al., 2015, p. 44, fig. 6.7; Tazawa and Nakamura, 2015, p. 169, fig. 7.1–7.7.
Hustedia nakornsrii Yanagida, 1970, p. 79, pl. 14, fig. 9.

Material.—Eleven specimens from localities SSK17, SSK24, SSK27 and SSK28: (1) external and internal moulds of a conjoined shell, NU-B2371; (2) internal moulds of two conjoined shells, with external moulds of the ventral valves, NU-B2372, 2373; (3) internal moulds of two conjoined shells, with external mould of the dorsal valves, NU-B 2303, 2374; (4) external and internal moulds of a dorsal valve, NU-B 2375; (5) external moulds of a dorsal valve, NU-B 2304; and (6) internal moulds of four dorsal valves, NU-B2305, 2323, 2324, 2376.

Remarks.—These specimens are referred to *Hustedia ratburiensis* Waterhouse and Piyasin (1970, p. 138, pl. 23, figs. 15–30), from the Wordian of Khao Phrik, southern Thailand, by the medium size (length 11 mm, width 7 mm in the best preserved specimen, NU-B2303; length 8 mm, width 7 mm in an average-sized specimen, CU40) and in having rounded costae which occur three close-set medianly and four pairs laterally on the dorsal valve. *Hustedia nakornsrii* Yanagida (1970, p. 79, pl. 14, fig. 9), from the Ratburi Limestone of Khao Phrik, is deemed to be conspecific with the present species. *Hustedia indica* (Waagen, 1883, p. 493, pl. 35, figs. 1, 2), from the Wargal Formation of the Salt Range, differs from *H. ratburiensis* in having fewer and broader costae on both valves.

Occurrence.—SK1, SK4 and KN1 units.

Distribution.—Sakmarian–Wuchiapingian: northeastern Japan (Nagaiwa–Sakamotozawa, Nakadaira and Takakurayama in the South Kitakami Belt), central Japan (Hida Gaien Belt), southwestern Japan (Mizukoshi in central Kyushu Kyushu), north-central Thailand (Khao Hin King) and southern Thailand (Khao Phrik, Khao Tok Nam and Ko Muk).

Order SPIRIFERIDA Waagen, 1883
Suborder SPIRIFERIDINA Waagen, 1883
Superfamily MARTINIOIDEA Waagen, 1883
Family MARTINIIDAE Waagen, 1883
Subfamily MARTINIINAE Waagen, 1883
Genus *MARTINIA* M'Coy, 1844

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

Martinia lata Grabau, 1936
(Fig. 33C–E)

Martinia semiplana var, *lata* Grabau, 1936, p. 239, pl. 21, figs. 1–3; Hayasaka and Minato, 1956, p. 146, pl. 23, fig. 3.
Martinia lata Grabau. Tazawa, 2008a, p. 38, fig. 5.7–5.14.

Material.—Three specimens from locality SSK17, external and internal moulds of three ventral valves, NU-B2294–2296.

Remarks.—These specimens are referred to *Martinia lata* Grabau, 1936, originally described by Grabau (1936, p. 239, pl. 21, figs. 1–3) as *Martinia semiplana* Waagen var. *lata* Grabau, 1936, from the Maping Formation of Guangxi, central-southern China, by the medium-sized, transversely subelliptical shell (length 17 mm, width 24 mm in the best preserved specimen, NU-B2294) and in having a shallow ventral sulcus. *Martinia semiplana* Waagen (1883, p. 536, pl. 43, fig. 4), from the Wargal Formation of the Salt Range, differs from *M. lata* in its smaller size and less transverse outline.

Occurrence.—KN1 Unit.

Distribution.—Asselian–Wuchiapingian: northeastern Japan (Nagaiwa–Sakamotozawa, Kamiyasse–Imo and Takakurayama in the South Kitakami Belt) and central-southern China (Guangxi).

Genus *JILINMARTINIA* Lee and Gu, 1980

Type species.—*Brachythyris shansiensis* Chao, 1929.

Jilinmartinia sp.
(Fig. 33H)

Material.—One specimen from locality SSK17, external and internal moulds of a conjoined shell, NU-B2293.

Remarks.—The single specimen from Nagaiwa–Sakamotozawa in the South Kitakai Belt is safely assigned to the genus *Jilinmartinia* Lee and Gu, 1980 by the large size (length about 33 mm, width about 85 mm), wider subcircular outline, moderately developed sulcus, external ornament consisting of fine concentric growth lines, and some radial vascular markings

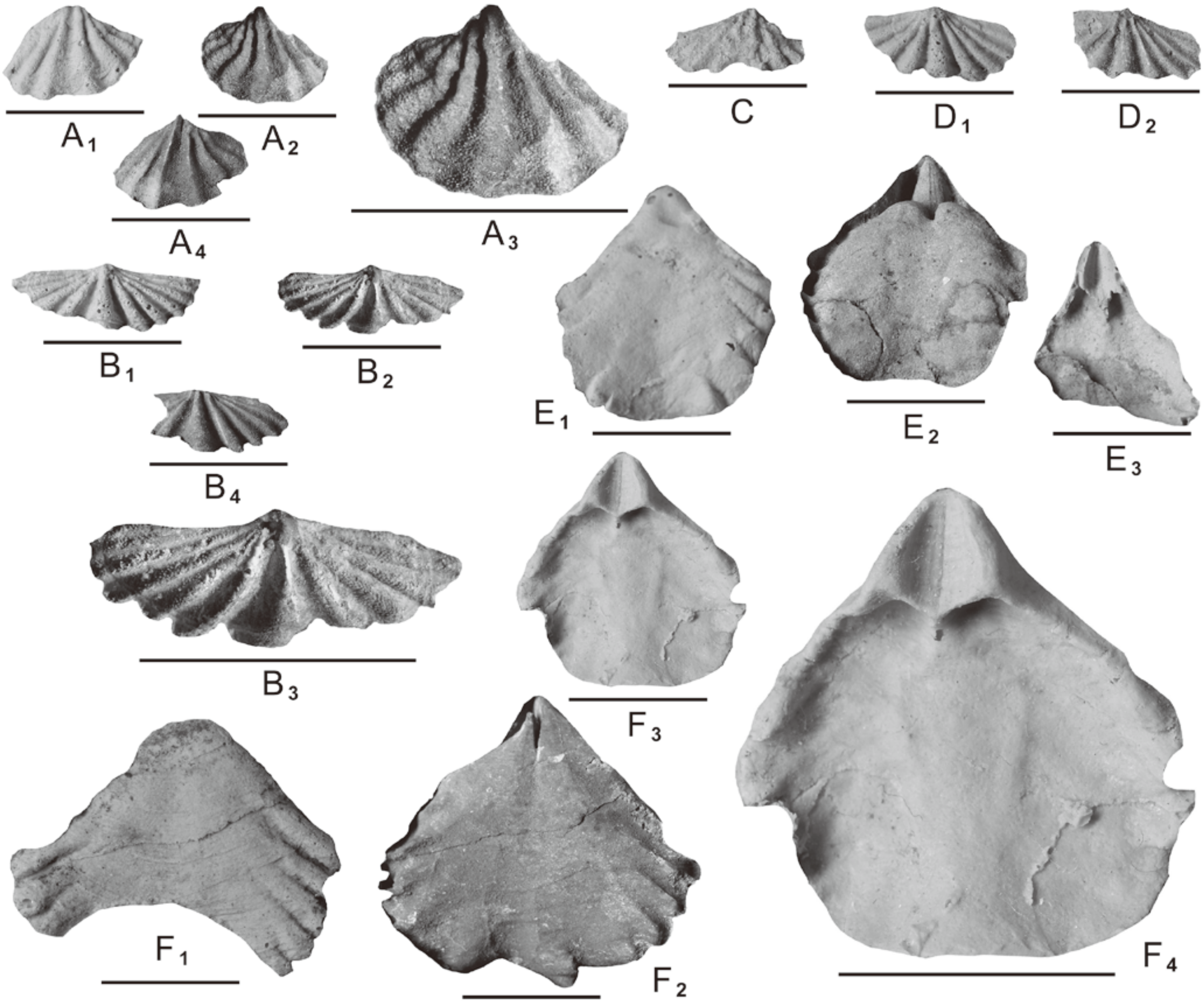

FIGURE 31. Brachiopods of the SK4 assemblage (2). **A–D,** *Crenispirifer sagus* Cooper and Grant; A, external latex cast (A_1), external mould (A_2, A_3) and internal mould (A_4) of ventral valve, NU-B2313; B, external latex cast (B_1), external mould (B_2, B_3) and internal mould (B_4) of dorsal valve, NU-B2318; C, external latex cast of ventral valve, NUB2315; D, external latex cast (D_1) and internal mould (D_2) of dorsal valve, NU-B2319; **E, F,** *Trasgu confinensis* (Schellwien); E, external latex cast (E_1), internal mould (E_2) and internal latex cast (E_3) of ventral valve, NU-B2308; F, external latex cast (F_1), internal mould (F_2) and internal latex cast (F_3, F_4) of ventral valve, NU-B2307. Scale bars are 1 cm.

in the ventral valve. The Kitakami species resembles the type species, *Jilinmartinia shansiensis* (Chao, 1929), originally described by Chao (1929, p. 55, pl. 9, figs. 1–3) as *Brachythyris shansiensis* Chao, 1929, from the Lichiachuan Formation (Asselian) of Gansu, northwestern China, in size and shape of the shell and external ornament of the ventral valve. But the Chinese species differs from the present species in the less transverse outline and in having narrower and deeper sulcus on the ventral valve. *Jilinmartinia sokolovi* (Tschernyschew, 1902, p. 166, pl. 8, fig. 3; pl. 39, fig. 4), from the Asselian of the Urals, is also a transverse *Jilinmartinia* species, but the Russian species differs from the Kitakami species in having two costae in the ventral sulcus.

Occurrence.—KN1 Unit.

Distribution.—Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Family INGELARELLIDAE Campbell, 1959a

Subfamily INGELARELLINAE Campbell, 1959a

Genus *MARTINIOPSIS* Waagen, 1883

Type species.—*Martiniopsis inflata* Waagen, 1883.

Martiniopsis sp.
(Fig. 33F)

Material.—One specimen from locality SSK17, external and internal moulds of a ventral valve, NU-B2297.

Remarks.—The sole specimen from Nagaiwa–Sakamotozawa can be assigned to the genus *Martiniopsis* Waagen, 1883 by long, slender subparallel dental adminicula in the ventral valve and in having no impressions of costae on the valve. The Kitakami species closely resembles *Martiniopsis inflata* Waagen (1883, p. 525, pl. 41, figs. 7, 8, text-fig. 9), from the Chhidru Formation of the Salt Range, in the medium size (length more than 17 mm, width about 35 mm) and transverse outline. *Martiniopsis cathaysiensis* Grabau (1936, p. 242, pl. 21, figs. 7, 8; pl. 24, fig. 9), from the Maping Limestone of Guangxi, central-southern China and Guizhou, southwestern China, is also transversely wider in outline but much smaller in size. An accurate comparison is difficult for this poorly preserved specimen.

Occurrence.—KN1 Unit.

Distribution.— Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Superfamily SPIRIFEROIDEA King, 1846
Family CHORISTITIDAE Waterhouse, 1968a
Subfamily CHORISTINAE Waterhouse, 1968a
Genus *CHORISTITES* Fischer de Waldheim, 1825

Type species.—*Choristites mosquensis* Buckman, 1908.

Choristites sp.
(Fig. 28A–E)

Material.—Six specimens from localities SSK14 and SSK27: (1) external and internal moulds of two ventral valves, NU-B2386, 2387; (2) external moulds of two ventral valves, NU-B2388, 2389; (3) external and internal moulds of a dorsal valve, NU-B2390; and (4) internal mould of a dorsal valve, NU-B2391.

Remarks.—These specimens can be assigned to the genus *Choristites* Fischer de Waldheim, 1825 by the large, transverse shell (length about 53 mm, width about 70 mm in the largest ventral valve specimen, NU-B2388; length about 48 mm, width about 85 mm in the largest dorsal valve specimen, NU-B2391), with a narrow, deep sulcus and a narrow, high fold, and ornamented with numerous flattened simple costae (7–9 in 10 mm at midlength) over both valves. The Nagaiwa–Sakamotozawa species resembles well *Choristites pavlovi* (Stuckenberg, 1905), redescribed by Chao (1929, p. 36, pl. 4, figs. 9, 10; pl. 5, figs. 1–4; pl. 6, figs. 5, 6) from the Taiyuan Formation of Shanxi, northern China, in size, shape and external ornament of shell. But accurate comparison is difficult for the ill-preserved specimens.

Occurrence.—SK1 Unit.

Distribution.—Sakmarian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt).

Suborder DELTHYRIDINA Ivanova, 1972
Superfamily RETICULARIOIDEA Waagen, 1883
Family ELYTHIDAE Fredericks, 1924
Subfamily PHRICODOTHYRIDINAE Caster, 1939
Genus *PHRICODOTHYRIS* George, 1932

Type species.—*Phricodothyris lucerna* George, 1932.

Phricodothyris asiatica (Chao, 1929)
(Fig. 27F, G)

Reticularia lineata Martin. Tschernyschew, 1902, p. 193, 574, pl 20, figs. 9–13.

Squamularia asiatica Chao, 1929, p. 91, pl. 11, figs. 12–14; Ozaki, 1931, p. 76, pl. 8, figs. 15–19, pl. 9, figs. 2–4; Grabau, 1934, p. 71, pl. 5, figs. 3, 4.

Neophricodothyris asiatica (Chao). Licharew, 1939, p. 109, pl. 27, fig. 6.

Phricodothyris asiatica (Chao). Mironova, 1967, p. 51, pl. 5, figs. 9, 10; Yanagida, 1967, p. 75, pl. 14, figs. 1, 2, 5, 7, text-fig. 11; Pavlova, 1969, p. 95, pl. 8, fig. 4; pl. 9, figs. 1, 2, text-figs. 60, 61; Ifanova, 1972, p. 141, pl. 13, figs. 5–10; Jin et al., 1974, p. 311, pl. 163, figs. 4–6; Lee and Gu, 1976, p. 298, pl. 136, figs. 1, 2; pl. 147, figs. 8–13; pl. 149, fig. 8; pl. 177, fig. 11; Yang et al., 1977, p. 450, pl. 179, fig. 5; Tong, 1978, p. 261, pl. 90, fig. 9; Zhan and Wu, 1987, p. 229, pl. 62, figs. 20–25; Kotlyar and Zakharov, 1989, pl. 18, fig. 6; pl. 19, fig. 12; Liang, 1990, p. 285, pl. 62, figs. 1–10; pl. 63, figs. 6–11; pl. 65, fig. 18, text-fig. 38; He et al., 1995, pl. 66, figs. 45–49; Carter and Poletaev, 1998, p. 172, fig. 27.19–27.32; Wang and Yang, 1998, p. 127, pl. 23, figs. 5,6, 9.

Material.— Ten specimens from locality SSK27: (1) external and internal moulds of three conjoined shells, NU-B2422–2424; (2) external and internal moulds of four ventral valves, NU-B2425–2428; and (3) external moulds of three ventral valves, NU-B2429–2431.

Description.—Shell medium in size for genus, slightly transverse suboval in outline; cardinal extremities rounded; hinge approximately half or less than maximum width at midlength; length 10 mm, width 13 mm in the best preserved specimen (NU-B2424). Ventral valve gently to moderately convex in lateral profile; sulcus absent or very weakly expressed. Dorsal valve slightly less convex than opposite valve; fold absent or very low. External surface of both valves ornamented with narrow distinct concentric lamellae, fringed by closely spaced, fine uniramous spines or spine bases; numbering 7–8 lamellae in 5 mm. Internal structures of both valves not well preserved.

Remarks.—These specimens are referred to *Phricodothyris*

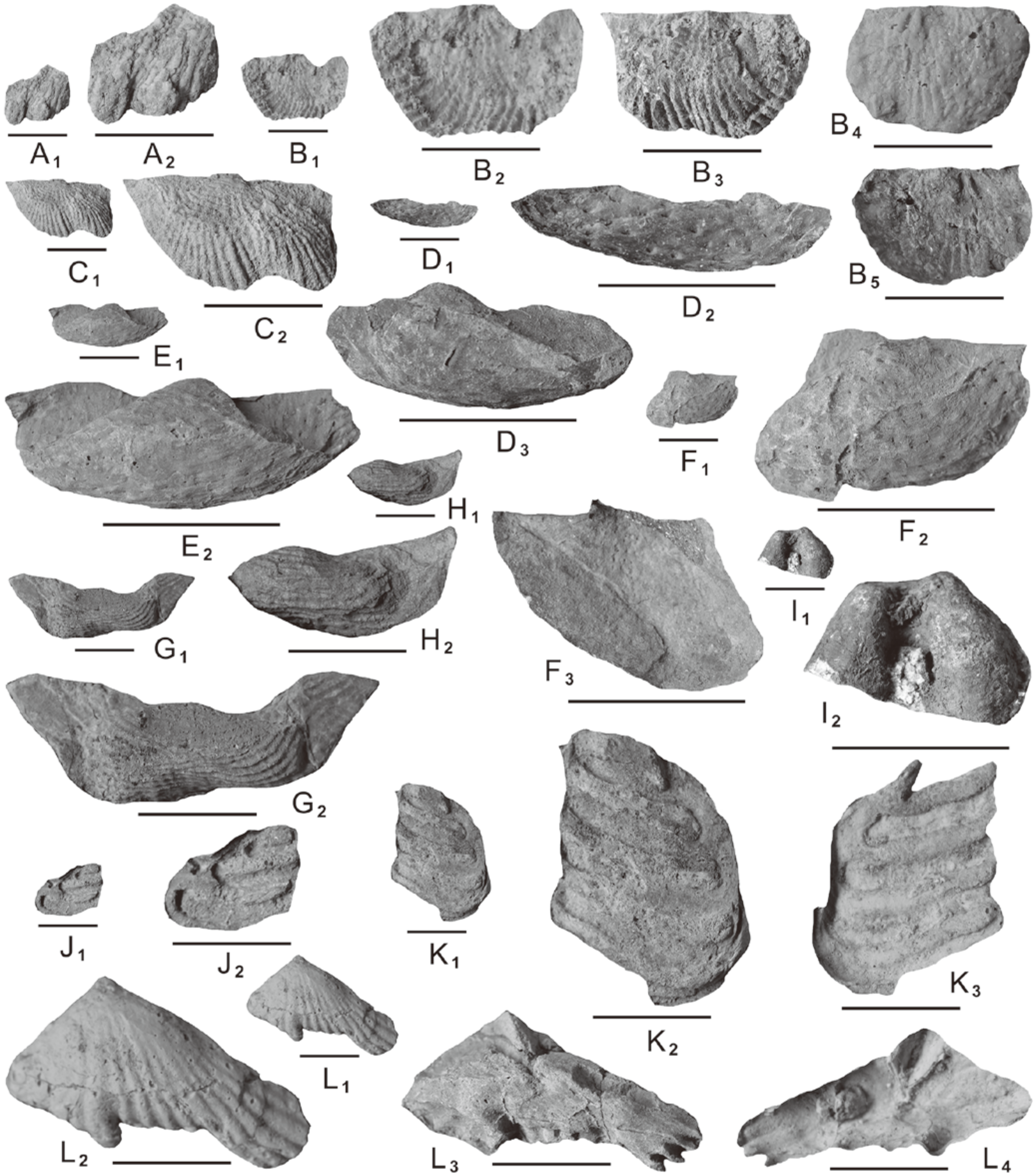

FIGURE 32. Brachiopods of the KN1 assemblage (1). **A–C,** *Transennatia insculpta* (Grant); A, external latex cast (A_1, A_2) of ventral valve, NU-B2282; B, external latex cast (B_1, B_2), external mould (B_3), internal latex cast (B_4) and internal mould (B_5) of dorsal valve, NU-B2283; C, external mould (C_1, C_2) of dorsal valve, NU-B2284; **D–F,** *Echinauris* sp.; D, external mould (D_1, D_2) and internal mould (D_3) of ventral valve, NU-B2287; E, external mould (E_1, E_2) of dorsal valve, NU-B2292; F, external mould (F_1, F_2) and internal mould (F_3) of dorsal valve, NU-B2289; **G, H,** *Anidanthus* sp.; G, external mould (G_1, G_2) of dorsal valve, NU-B2302; H, external mould (H_1, H_2) of dorsal valve, NU-B2301; **I,** *Dicystoconcha lapparenti* Ternier and Termier, internal mould (I_1, I_2) of ventral valve, NU-B2280; **J, K,** *Pseudoleptodus* sp.; J, internal mould (J_1, J_2) of ventral valve, NU-B2300; K, internal mould (K_1, K_2) and internal latex cast (K_3) of ventral valve, N(U-B2299; **L,** *Stenoscisma* sp., external latex cast (L_1, L_2), internal mould (L_3) and internal latex cast (L_4) of ventral valve, NU-B2306. Scale bars are 1 cm.

asiatica (Chao), Originally described by Chao (1929, p. 91, pl. 11, figs. 12–14) as *Squamularia asiatica* Chao, 1929 from the lower Permian of Guizhou, southwestern China, in the small, transversely suboval shell, ornamented with distinct lamellae, which are fringed with numerous fine uniramous spines. *Phricodothyris echinata* Chao (1929, p. 86, pl. 8, figs. 17–19), from the Penchi and Taiyuan series of Gansu and Shanxi, northern China, differs from *P. asiatica* in the less transverse outline and in having broader and less strong concentric lamellae on the both valves. The type species, *Phricodothyris lucerna* George (1932, p. 546, pl. 35, fig. 2), from the upper Visean of Northumberland, England, differs from the present species in the larger size and less transverse outline.

Occurrence.—SK1 Unit.

Distribution.—Moscovian–Wuchiapingian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), northern Canada (Ellesmere Island), northern Russia (Pechora Basin), western Russia (Transcaucasus), central Russia (southern Urals), northwestern China (Xinjiang), northern China (Inner Mongolia and Shanxi), eastern China (Shandong and Zhejiang), central-southern China (Hunan and Guangxi), southwestern China (Guizhou and Sichuan) and north-central Thailand (Thum Nam Maholan).

Order SPIRIFERINIDA Ivanova, 1972
Suborder SPIRIFERINIDINA Ivanova, 1972
Superfamily PENNOSPIRIFERINOIDEA Dagys, 1972
Family PARASPIRIFERINIDAE Cooper and Grant, 1976
Genus *CALLISPIRINA* Cooper and Muir-Wood, 1951

Type species.—*Spiriferina ornata* Waagen, 1883.

Callispirina ornata (Waagen, 1883)
(Fig. 29A, B)

Spiriferina ornata Waagen, 1883, p. 505, pl. 50, figs. 1, 2; Tschernyschew, 1902, p. 113, 515, pl. 12, figs. 8–10: pl. 37, figs. 8–11; Sokolskaya in Sarytcheva and Sokolskaya, 1952, p. 226, pl. 66, fig. 383.
Callispirina ornata (Waagen). Mironova, 1967, p. 49, pl. 5, figs. 4, 5; Kulikov, 1974, p. 102, pl. 7, fig. 6; Kalashnikov, 1980, p. 94, pl. 36, fig. 9; Kalashnikov, 1998, p. 75, pl. 26, fig. 5; pl. 31, figs. 1–5.
Punctospirifer ornata (Waagen). Lee et al., 1980, p. 420, pl. 155, fig. 22; pl. 179, figs. 1, 19, 20.
Callispirina sp. Tazawa and Shintani, 2014, p. 35, fig. 6.10.

Material.—Two specimens from localities SSK27 and SSK28: (1) external and internal moulds of a ventral valve, NU-B2392; and (2) external and internal moulds of a dorsal valve, NU-B2393.

Remarks.—These specimens are referred to *Callispirina ornata* (Waagen, 1883), originally described by Waagen (1883, p. 505, pl. 50, figs. 1, 2) from the Chhidru Formation of the Salt Range, Pakistan, by the small, transverse shell (length 11 mm, width 13 mm in the largest specimen, NU-B1517), coarse rounded costae (numbering 3–4 on each lateral flank) and closely spaced, imbricate lamellae and numerous pustules over the both valves. The present specimens were previously described by Tazawa and Shintani (2014, p. 35, fig. 6.10) as *Callispirina* sp. from the basal part of the Nakadaira Formation (Sakmarian) of Kamiyasse in the South Kitakami Belt. *Callispirina rotunda* Cooper and Grant (1976, p. 2743, pl. 705, figs. 66–82), from the Bell Canyon Formation of Texas, differs from *C. ornata* in larger size and in having more numerous costae on lateral flanks.

Occurrence.—SK1 Unit.

Distribution.—Kasimovian–Changhsingian: northeastern Japan (Nagaiwa–Sakamotozawa and Kamiyasse in the South Kitakami Belt), northern Russia (Timan, Vaygach Island and northern Urals), western Russia (Moscow Basin), central Russia (southern Urals), northeastern China (Heilongjiang and Jilin) and Pakistan (Salt Range).

Family SPIRIFERELLINIDAE Ivanova, 1972
Genus *SPIRIFERELLINA* Fredericks, 1924

Type species.—*Terebratulites cristatus* von Schlotheim, 1816.

Spiriferellina cristata (von Schlotheim, 1816)
(Fig. 29C–F)

Terebratulites cristatus von Schlotheim, 1816, p. 28, pl. 1, fig. 3.
Spirifer cristatus (Schlotheim). de Koninck, 1843, p. 240, pl. 15, fig. 5.
Spiriferina cristata (Schlotheim). Tschernyschew, 1902, p. 115, 517, pl. 37, figs. 1, 2; Ozaki, 1931, p. 172, pl. 15, fig. 14; Malzahn, 1937, p. 40, pl. 3, figs. 26, 27.
Spiriferellina cristata (Schlotheim). Heritsche, 1935, p. 364, pl. 2, fig. 22; Heritsche, 1938, p. 133, pl. 7, figs. 15–19; Campbell, 1959b, p. 358, pl. 59, figs. 1–9; pl. 60, fig. 3, text-fig. 5; Schréter, 1963, p. 144, pl. 8, figs. 11–14; Alexandrov and Einor, 1979, p. 91, pl. 38, figs. 2, 3; Lee et al., 1980, p. 422, pl. 179, figs. 3, 6–8; Kalashnikov, 1998, p. 75, pl. 30, fig. 3; pl. 32, figs. 1, 2; Wang and Yang, 1998, p. 125, pl. 22, figs. 9, 13, 14; Fan and He, 1999, p. 146, pl. 33, figs. 11–20; Wang and Zhang, 2003, p. 168, pl. 34, figs. 12–16; pl. 50, figs. 14, 16; Tazawa, 2012, p. 42, figs. 3.17–3.19.
Punctospirifer cristata (Schlotheim). Dunbar, 1955, p. 149, pl. 29, figs. 13–20.

Material.—Twenty-eight specimens from localities SSK14, SSK27 and SSK28: (1) external and internal moulds of a conjoined shell, NU-B2394; (2) internal mould of a conjoined shell, with external mould of the ventral valve, NU-B2395; (3) internal mould of a conjoined shell, with external mould of the dorsal valve, NU-B2396; (4) internal moulds of three conjoined shells, NU-B2397–2399; (5) external and internal moulds of eleven ventral valves, NU-B2400–2410; (6) internal moulds of two ventral valves, NU-B2411, 2412; (7) external and internal

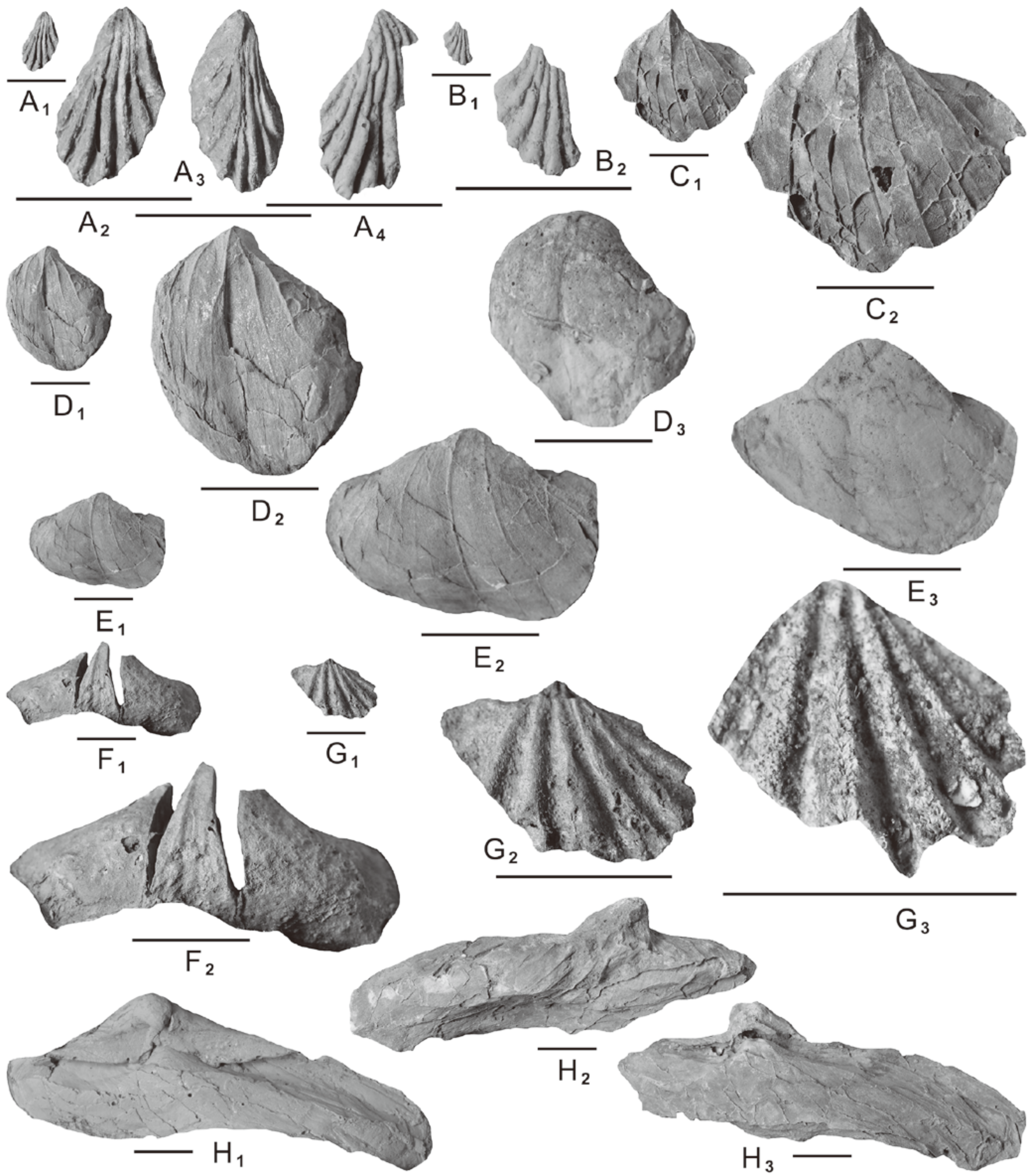

FIGURE 33. Brachiopods of the KN1 assemblage (2). **A, B,** *Hustedia ratburiensis* Waterhouse and Piyasin; A, ventral internal mould (A_1, A_2), dorsal internal mould (A_3) and dorsal external latex cast (A_4) of conjoined shell, NU-B2303; B, external latex cast (B_1, B_2) of dorsal valve, NU-B2304; **C–E,** *Martinia lata* Grabau; C, internal mould of ventral valve, NU-B2295; D, internal mould (D_1, D_2) and external latex cast (D_3) of ventral valve, NU-B2296; E, internal mould (E_1, E_2) and external latex cast (E_3) of ventral valve, NUB2294; **F,** *Martiniopsis* sp., internal mould (F_1, F_2) of ventral valve, NU-B2297; **G,** *Crenispirifer sagus* Cooper and Grant, internal mould (G_1, G_2) and external latex cast (G_3) of dorsal valve, NU-B2298; **H,** *Jilinmartinia* sp., dorsal external latex cast (H_1), ventral internal mould (H_2) and dorsal internal mould (H_3) of conjoined shell, NUB2293. Scale bars are 1 cm.

moulds of seven dorsal valves, NU-B2413–2419; (8) external mould of a dorsal valve, NU-B2420; and (9) internal mould of a dorsal valve, NU-B2421.

Remarks.—These specimens are referred to *Spiriferellina cristata* (von Schlotheim, 1816), redescribed and refigured by Campbell (1959b, p. 358, pl. 59, figs. 1–9; pl. 60, fig. 3, text-fig. 5) on the syntype and lectotype specimens, from the Zechstein of Thuringia, Germany, in the small, transverse shell (length 16 mm, width 24 mm in the largest specimen, NU-B2400), and 4–5 pairs of rounded costae on both ventral and dorsal valves. *Spiriferellina fredericksi* Tazawa (2014, p. 19, fig. 3.5–3.7), from the lower part of the Kamiyasse Formation (Wordian) of Kamiyasse–Imo, South Kitakami Belt, is readily distinguished from *S. cristata* in its much larger size.

Occurence.—SK1 Unit.

Distribution.—Kasimovian–Changhsingian: northeastern Japan (Nagaiwa–Sakamotozawa and Kesennuma in the South Kitakami Belt), northern Russia (Timan and northern Urals), Greenland, Germany, Austria (Carnian Alps), Hungary, central Russia (southern Urals), northwestern China (Xinjiang), northern China (Inner Mongolia and Shanxi) and northeastern China (Heilongjiang).

Genus *CRENISPIRIFER* Stehli, 1954

Type species.—*Spiriferina angulata* King, 1931.

Crenispirifer sagus Cooper and Grant, 1976
(Figs. 31A–D, 33G)

Crenispirifer sagus Cooper and Grant, 1976, p. 2715, pl. 718, figs. 1–15.

Material.—Nine specimens from localities SSK17 and SSK24: (1) external and internal moulds of a ventral valve, NU-B2313; (2) external moulds of three ventral valves, NU-B2314–2316; (3) internal mould of a ventral valve, NU-B2317, (4) external and internal moulds of three dorsal valves, NU-B2298, 2318, 2319; and (5) internal mould of a dorsal valve, NU-B2320.

Description.—Shell small in size for genus, transversely subelliptical in outline, with greatest width at slightly anterior to hinge; cardinal extremities rounded; length 8 mm, width about 11 mm in the largest ventral valve specimen (NU-B2313); length 6 mm, width 12 mm in the largest dorsal valve specimen (NU-B2318). Ventral valve moderately convex in lateral profile, most convex at umbonal region; umbo small, incurved; sulcus narrow, deep; lateral slopes gently convex. Dorsal valve flatly convex; umbo slightly swollen; fold narrow, moderately high, with rounded crest. External surface of both valves ornamented with strong costae, numbering 4–5 on each side; numerous very fine pustules over the valves; concentric rugae or growth laminae not observed. Internal structures of both valves not well preserved, except for a short, thin median septum in the ventral valve.

Remarks.—These specimens are referred to *Crenispirifer sagus* Cooper and Grant (1976, p. 2715, pl. 718, figs. 1–15), from the Bone Spring Formation (lower Leonardian) of Texas, by the small-sized, flatly biconvex shell, ornamented with rather numerous costae on the both valves. *Crenispirifer nakamurai* Tazawa and Shintani (2014, p. 36, figs. 6.11, 6.12), from the Nakadaira Formation (Sakmarian) of Nakadaira, South Kitakami Belt, is readily distinguished from the present species by its fewer and broader costae on both ventral and dorsal valves. Two small-sized *Crenispirifer* species, *C. effrenus* Cooper and Grant (1976, p. 2712, pl. 718, figs. 16–29) from the Cherry Canyon Formation of Texas, and *C. myllus* Cooper and Grant (1976, p. 2714, pl. 718, figs. 30–85; pl. 719, figs. 36–40) from the Bell Canyon Formation of Texas, differ from *C. sagus* in the more strongly biconvex shell and in having growth laminae on the both valves.

Occurrence.—SK4 and KN1 units.

Distribution.—Artinskian–Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt) and USA (Texas).

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

<　地名・地層名　>

Endosawa ……… エンドウ沢
Hikami Granite ……… 氷上花崗岩
Hikoroichi-cho ……… 日頃市町
Hosoo Formation ……… 細尾層
Ichinoseki ……… 一関
Imahorazawa Valley ……… イマホラ沢
Imo ……… 飯森
Ishibashi ……… 石橋
Kabayama Stage ……… 樺山階
Kamaishi ……… 釜石
Kamisakamotozawa ……… 上坂本沢
Kamiishibashi ……… 上石橋
Kamijo ……… 上条
Kamiyasse–Imo ……… 上八瀬–飯森
Kanokura Formation ……… 叶倉層
Kawaguti (Kawaguchi) Stage ……… 川口階
Kesengawa River ……… 気仙川
Kesennuma ……… 気仙沼
Maiya ……… 米谷
Mizukoshi ……… 水越
Motoiwazawa Sandstone Member ……… 元岩沢砂岩部層
Mt. Goyosan ……… 五葉山
Mt. Takamoriyama ……… 高森山
Nabekoshiyama Formation ……… 鍋越山層
Nagaiwa Formation ……… 長岩層
Nagaiwa–Sakamotozawa ……… 長岩–坂本沢
Nakadaira ……… 中平
Nakazato Formation ……… 中里層
Nedamo Belt ……… 根田茂帯
Nishigori (Nishikori) Formation ……… 西郡層
Ofunato City ……… 大船渡市
Ogatsu ……… 雄勝
Onimaru Formation ……… 鬼丸層
Ono Formation ……… 大野層
Rokuro-toge ……… 六郎峠
Sakamotozawa Formation ……… 坂本沢層
Sakarigawa River ……… 盛川
Setamai ……… 世田米
Shiraishi-toge ……… 白石峠
Shiratorizawa Limestone Member ……… 白鳥沢石灰岩部層
Sumita-cho ……… 住田町
Takakurayama ……… 高倉山
Takougawa River ……… 鷹生川
Tashiroyama Limestone Member ……… 田代山石灰岩部層
Tashiroyashiki ……… 田代屋敷
Tassobe ……… 達曽部
Tono ……… 遠野
Toyoma Series (Formation) ……… 登米統（層）
Usuginu-type conglomerate ……… 薄衣型（式）礫岩
Yubanosawa Slate Member ……… 湯場沢粘板岩部層
Yukizawa (Yukisawa) Series ……… 雪沢統