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Visean – Moscovian conodont biostratigraphy of the Ko-yama Limestone Group, Akiyoshi Belt, SW Japan

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Abstract

Carboniferous clastic carbonates associated with basaltic pyroclasts and spicular chert beds in the lower part of the Ko-yama Limestone Group contain the Visean – Moscovian conodont succession of *Gnathodus semiglaber* (late Visean), *Gnathodus praebilineatus – Lochriea multinodosa* (late Visean), *Lochriea ziegleri – Gnathodus girtyi girtyi* s.l. (early Serpukhovian), *Neoganthodus symmetricus – Idiognathodus primulus* (middle – late Bashkirian), and *Idiognathoides convexus – Gondolella clarki* (early Moscovian). The FAD of *Lochriea ziegleri* marks the Visean/Serpukhovian boundary in the section. The middle – late Bashkirian *Neoganthodus symmetricus – Idiognathodus primulus* Fauna is a mixed fauna containing reworked Serpukhovian and older elements possibly related to an erosional event after the Early Bashkirian global eustatic low-stand. The revision of conodont zonal correlation in the Akiyoshi Belt was examined with the Mississippian/Pennsylvanian boundary considering the FAD of *Declinognathodus noduliferus* in the previously proposed zones in the similar Hina, Atetsu, Akiyoshi and Omi limestone groups. *Idiognathodus craticulinodosus* n. sp. was described as the middle – late Bashkirian to early Moscovian index.

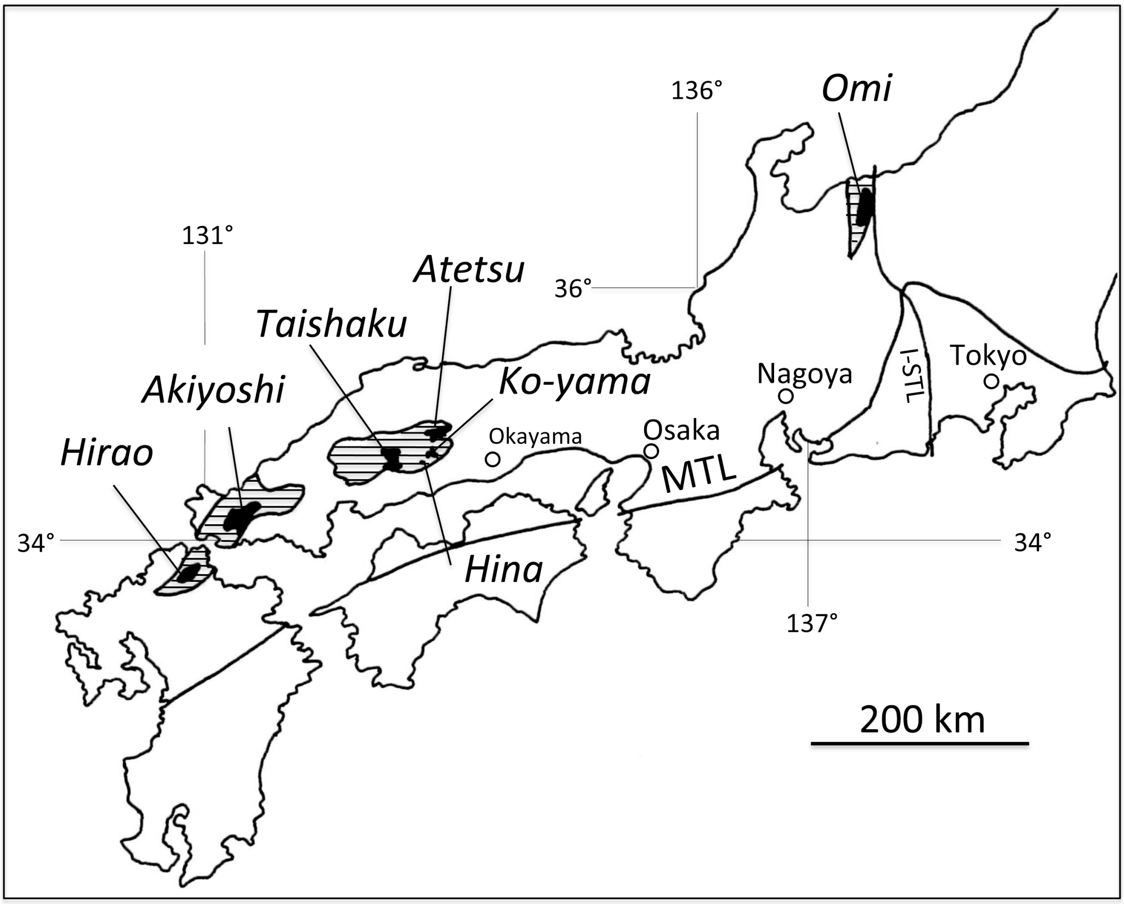
Keywords: *conodont, biostratigraphy, Visean, Serpukhovian, Bashkirian, Ko-yama Limestone Group, Akiyoshi Belt, SW Japan*

INTRODUCTION

The Carboniferous conodont biostratigraphy in Japan has been studied mainly during the late 20th Century (Igo and Koike 1964; Koike 1967; Nogami 1970; Igo 1973; Igo and Kobayashi 1974; Watanabe 1975; Igo and Igo 1979; Haikawa 1988). In the Akiyoshi Belt, one of the Permian accretionary complex (PAC) of the Inner Zone of SW Japan (Isozaki 1997; Sano et al. 2004), large limestone masses associated with basaltic pyroclastics at their bases occur, known as the Akiyoshi, Taishaku, Atetsu, Hina, and Ko-yama limestones (text-fig. 1). In the sedimentologic study of the Akiyoshi Limestone Group, Nakashima and Sano (2007) proposed a Mississippian to Permian mid-oceanic atoll-type origin, fragments of the buildup being resedimented in a slope-to-basin facies. Mizuno (1997) carried out a conodont study in the Hina Limestone across the Mississippian–Pennsylvanian boundary.

The conodont faunas in the present paper originated from the clastic carbonates in the lower part of the Ko-yama Limestone Group, West of Okayama (text-fig. 2). The faunal succession appeared correlative with that of the global Visean, Serpukhovian, Bashkirian and Moscovian stages and the Visean/Serpukhovian boundary was discussed in relation to the occurrence of *Lochriea* species (e.g. Blanco-Ferrera et al. 2005; Groves et al. 2003; Higgins 1975; Kullmann et al. 2008; Nemyrovska 1999, 2005; Nikolaeva et al. 2009; Somerville 2008).

GEOLOGICAL SETTING



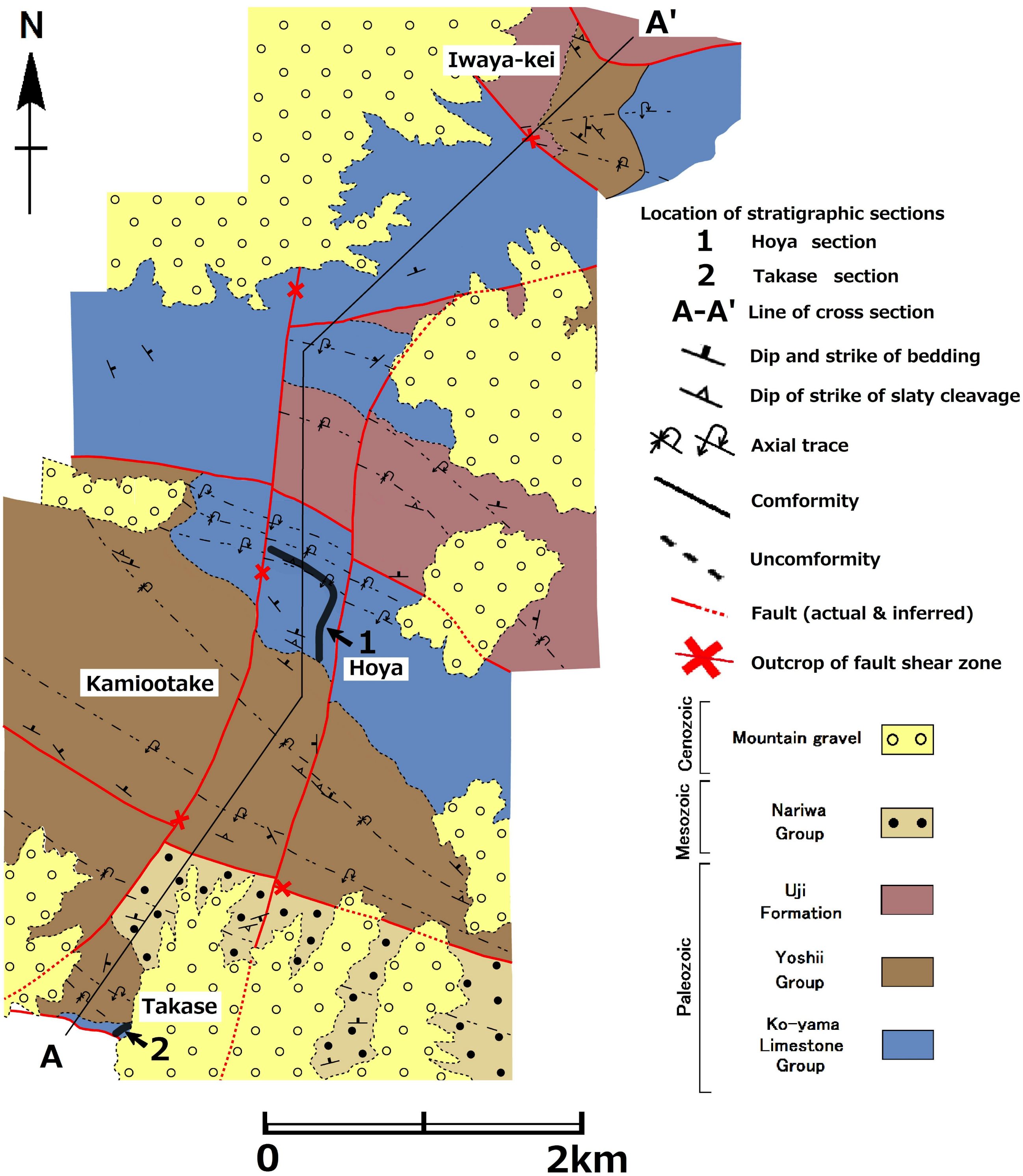
TEXT-FIGURE 1
Locality map of Carboniferous limestones (massive) in the Akiyoshi Belt (hatched).
MTL: Median Tectonic Line; I-STL: Itoigawa – Shizuoka Tectonic Line.

Ko-yama Limestone Group

The Lower Carboniferous – Middle Permian Ko-yama Limestone Group (after Yoshimura 1961: Koyama Group) is one of the large limestone-chert masses in the Akiyoshi Belt (text-figs. 2, 3), thrusted upon the turbiditic Upper Permian Yoshii Group, and unconformably overlain by the mudstone-sandstone Middle Permian Uji Formation that contains small lenses of *Yabeina* limestone breccia (Yoshimura 1961). The Koyama Limestone (Yokoyama et al. 1979) corresponds to the Lower and Middle formations of Yoshimura (1961)'s three-fold subdivision of the Koyama Group (text-fig. 4). In their biostratigraphic study, Yokoyama et al. (1979) found that the Koyama Limestone ranges from Carboniferous to Middle Permian. Six foraminifer zones: *Endothyra, Millerella, Pseudostafella, Profusulinella, Fusulinella – Fusulina* and *Pseudoschwagerina – Parafusulina* were recognized.

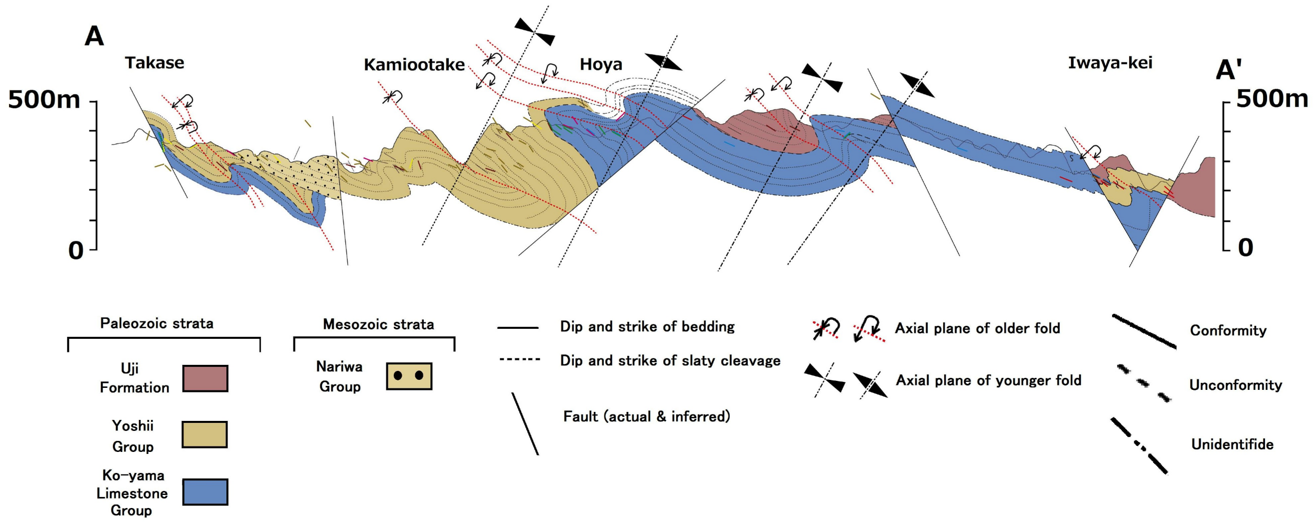
The lithofacies of the Ko-yama Limestone Group encompasses not only a build-up of coral-related biota, but another type of carbonate that is commonly composed of crinoid, bryozoan and brachiopod bioclasts with more or less basaltic pyroclasts intercalations. In addition, some pillow basalts, alternating beds of spiculitic chert, micritic limestone, and acidic tuff beds that also contain large amount of spongy spicules, are intercalated in the carbonates of the studied Carboniferous successions (text-figs. 2, 3, 5). Yokoyama et al. (1979) also considered the carbonates to have been formed by the transportation of carbonate clasts into the chert depositional deeper open sea bottom, because the spongolite cherts commonly intercalated in the lower part of the Koyama Limestone that is dominated by the crinoid – bryozoan bioclastic packstone.

The shed-model of Nakashima and Sano (2007) for the limestone – basaltic pyroclastic sequence with associations of spiculitie cherts in the Akiyoshi Limestone Group suggests a marginal deep and slope facies around the mid-oceanic atoll-type buildup. The question about the association of acidic tuffs in particular horizons still remains open. Inada et al. (2012a, b) have studied the lithostratigraphic succession in the lower part of the Ko-yama Limestone Group in the Takase and Hoya sections,



TEXT-FIGURE 2
Geological map of the Ko-yama Limestone Group with location of the Takase and Hoya sections in the Ko-yama area, Okayama Prefecture (after Inada et al. 2012a).

and the Hoya section proved that of the Yokoyama et al. (1979) was upside-down. The stratigrapic sequence consists of two sections, and the Takase presumably older than the Hoya sections.



TEXT-FIGURE 3
Structural profile of the Ko-yama Limestone Group along the A-A' line in text-fig. 2 (after Inada et al. 2012a).

Koyama Group (Yoshimura 1961)	Koyama Limestone (Yokoyama et al. 1979)	Ko-yama Limestone Group (Ishida et al. This study)
Lower Formation (200 m): crinoidal limestone in association with reddish purple basaltic pyroclastics, some chert beds or thin bands Middle Formation (250 m): massive limestone with association of chert and basaltic pyroclastics. Upper Formation (100 m): cherts with limestone lenses of *Parafusulina – Neoschwagerina* Zone	Koyama Limestone: corresponds to Yoshimura (1961)'s Lower and Middle formations. Its lower part mainly consists of crinoid – bryozoan bioclastic packstone. The six foraminifer zones: *Endothyra*, *Millerella*, *Pseudostafella*, *Profusulinella*, *Fusulinella – Fusulina* and *Pseudoschwagerina – Parafusulina* (Occurrence and biostratigraphic horizon have not been shown.)	Lower part of KLG: corresponds to Yoshimura (1961)'s Lower and lower part of Middle formations. Studied Hoya section proved that of Yokoyama et al. (1979) was upside-down (Inada et al. 2012a, b). ***Takase section*** (ca 30 m base of KLG): basaltic pyroclastic breccia lime- to rudstone gradually change to tuffaceous grainstone with crinoid and brachiopod, then packstone beds ***Hoya section*** (nearly 300 m of lower KLG): crinoid grainstone and packstone with basaltic pyroclasts (lower part), spicularite – siliceous tuff beds, micrite beds with spicular cherts and wackestone (upper part).

TEXT-FIGURE 4
Lithostratigrahic correlation of the lower part of the Ko-yama Limestone Group.

Takase Section

In the Takase area, an about 30 m thick section represents the basal part of the Ko-yama Limestone Group (text-fig. 5), is composed of basaltic pyroclastic breccia limestone to rudstone (120212-22B BL) that gradually change into the overlying tuffaceous grainstone with crinoids and brachiopod shells (text-fig. 6: C, 120212-22 LS), then followed by packstone beds (120212-23 LS)

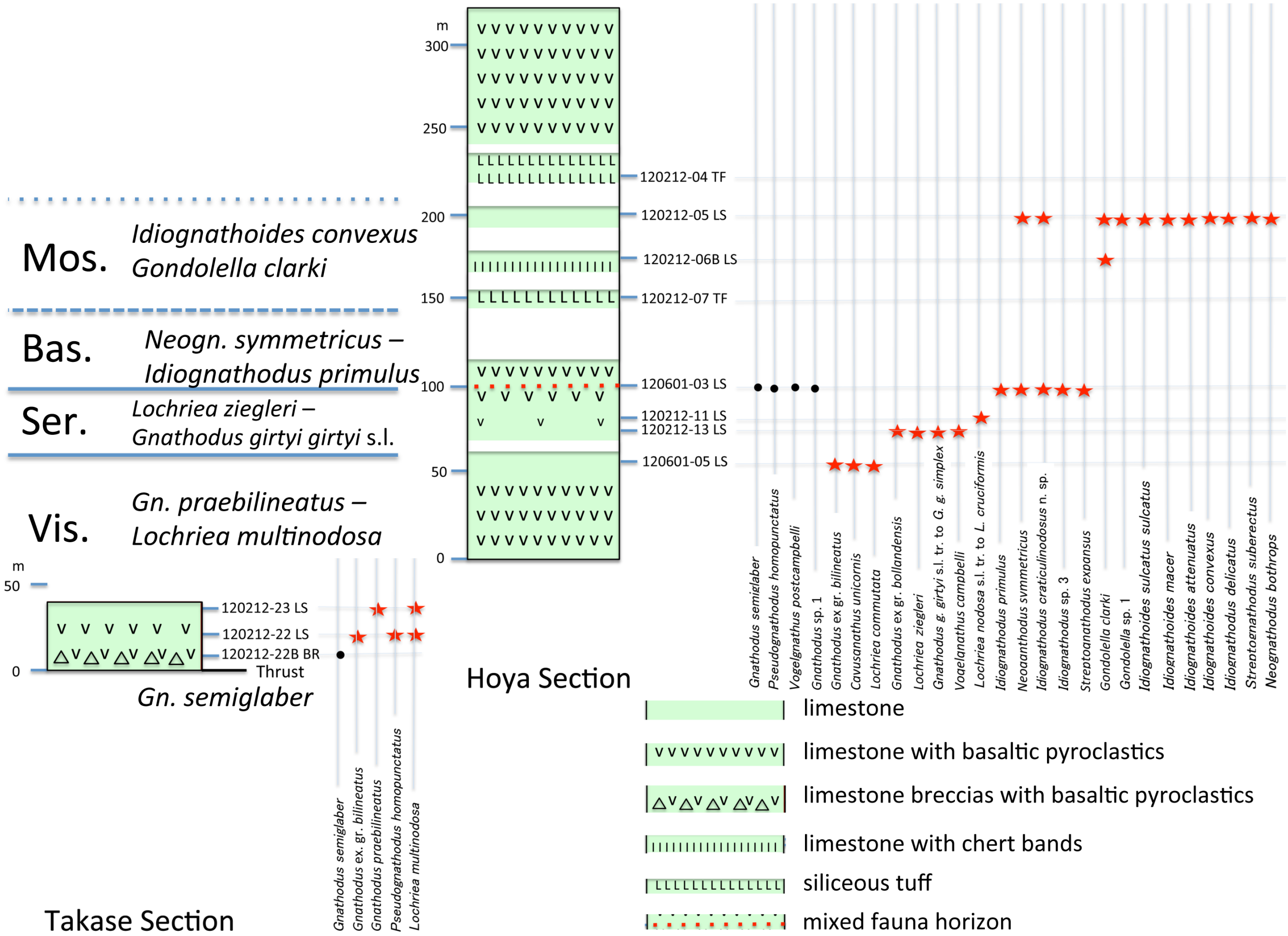
Hoya Section

In the Hoya area, the nearly 300 m thick lower part of the Ko-yama Limestone Group (text-fig. 5) is mainly composed of crinoid grainstone and packstone with common association of basaltic pyroclastics. Conodonts were obtained from a packstone bed (horizon 120601-05 LS), crinoid packstones with basaltic pyroclastics (horizons 120212-13 LS; 120212-11 LS: text-fig. 6: D; 120601-03 LS: text-fig. 6: A, B), a micrite bed alternating with spiculite chert (120212-06B LS) and a wackestone (120212-05 LS) in ascending order (text-fig. 5). The lithological turnover that is characterized by the common association of spicularite – siliceous tuff beds was recognized in the upper part of the section (above the 120601-03 LS). The intercalation of spicular chert bands in micritic limestones is also recognized in the upper part of the section.

RESULTS AND DISCUSSION

Conodonts from the Ko-yama Limestone Group

The conodont faunas originate from the lower part of the Ko-yama Limestone Group in the Takase and Hoya sections (text-fig. 7). Eleven conodont samples were studied, and nine samples yield useful Specimens. The conodont elements were picked under the microscope after chemical disolution of the



TEXT-FIGURE 5
Lithostratigraphy of the Takase and Hoya sections with the occurrence of conodonts (P_1 elements) in the lower part of the Ko-yama Limestone Group. Black circle: reworked element from the lower horizon.

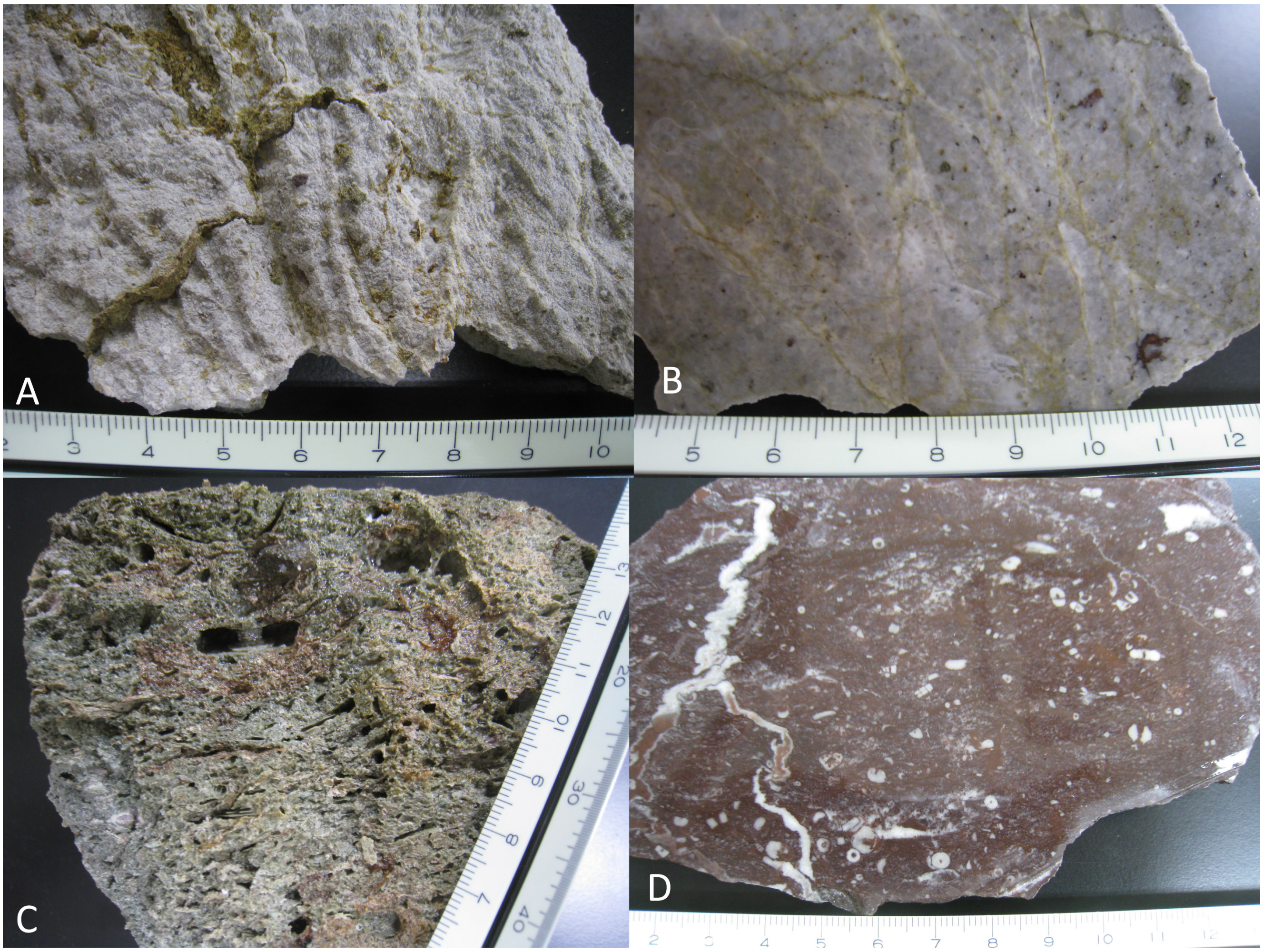
carbonates (2 – 4 kg per sample) in diluted acetic acid (ca. 17 %) and sieving by #250 (opening 0.063 mm). The residual grains larger than 0.063 mm were separated by heavy liquid (Tetrabromoethane: d = 2.957 – 2.977 gr/cm^3). Conodonts are found in the heavy fraction. The extracted conodont P_1 elements have a high potential for chronological analysis (plates 1, 2). The occurrence of identified P_1 specimens is shown in text-fig. 7.

Conodont zones in the Takase and Hoya sections

Based on the following succession of conodont faunas, five association zones including one estimated zone from the basal conglomerate were named by two taxa in the Takase and Hoya sections in ascending order.

***Gnathodus semiglaber* Zone**
Faunal composition: *Gnathodus semiglaber*.
Occurrence: TAKASE 120212-22B BL.
Age: Late Visean.
Remarks*:* The supposed oldest fauna was obtained from a wackestone block in the basaltic pyroclastic breccia in the basal part of the group.

***Gnathodus praebilineatus – Lochriea multinodosa* Zone**
Faunal composition: *Gnathodus praebilineatus*, *Gnathodus* ex gr. *bilineatus*, *Pseudognathodus homopunctatus*, *Lochriea multinodosa*, *Lochriea commutata* and *Cavusgnathus unicornis*.
Occurrence: 120212-22 LS (grainstone bed with crinoids and brachiopod shells), 120212-23 LS (packstone beds); 120601-05 LS (packstone bed).
Age: late Visean.
Remarks*:* The age of this fauna is well controlled by the co-occurrence of *Gnathodus praebilineatus* and *Lochriea multinodosa*. *Cavusgnathus unicornis* associates in the upper horizon. Somerville (2008) mentioned that large robust forms of P_1 including *Cavusgnathus* characterize the conodont fauna in the

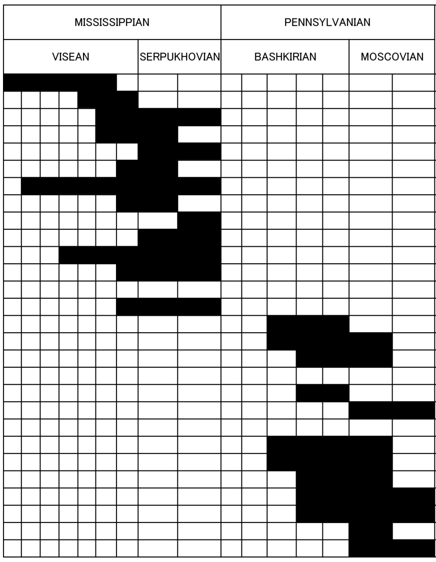


TEXT-FIGURE 6
A: crinoid packstone with basaltic pyroclastics (HOYA 120601-03), surface was eroded by acetic acid. B: crinoid packstone with basaltic pyroclastics (HOYA 120601-03), slub surface. dark spots are basaltic pyroclastics. C: tuffaceous grainstone with crinoids and brachiopod shells (TAKASE 120212-22), after de-carbonate by acetic acid. D: crinoid packstone with fine basaltic pyroclastics (HOYA 120212-11) showing purple color.

shallow-water platforms of the period. It is supposed that the specimen of *Cavusgnathus unicornis* was transported from the shallow area as a detrital crust, because surface of the obtained large specimens were rounded and the detail texture was eroded off (pl. 1, fig. 6).

***Lochriea ziegleri* – *Gnathodus girtyi girtyi* s.l. Zone**
Faunal composition: *Lochriea ziegleri*, *Gnathodus* ex gr. *bollandensis*, *Gnathodus girtyi girtyi* s.l. transition to *G. g. simplex*, *Vogelgnathus campbelli*, *Lochriea nodosa* s.l. transition to *L. cruciformis*.
Occurrence: 120212-13 LS (crinoid packstone with basaltic pyroclastics), 120212-11 LS (text-fig. 6: D; crinoid packstone with fine basaltic pyroclastics).
Age: early Serpukhovian.
Remarks: Transitional forms of *Gnathodus girtyi girtyi* s.l. transition to *G. g. simplex* and *Lochriea nodosa* s.l. transition to *L. cruciformis* were recognized from the lower horizons.

***Neoganthodus symmetricus* – *Idiognathodus primulus* Zone**
Faunal composition: *Idiognathodus primulus*, *Neoganthodus symmetricus*, *Idiognathodus craticulinodosus* n. sp., *Idiognathodus* sp. 3, *Streptognathodus expansus*.
Occurrence: 120601-03 LS (text-fig. 6: A, B; crinoid packstone: Serpukhovian and Visean elements were mixed).
Age: middle – late Bashkirian.
Remarks: The fauna from the Hoya 120601-03 LS (text-figs. 5, 6: A, B; crinoid packstone) contains reworked late Visean to Serpukhovian P_1 elements of *Gnathodus semiglaber*, *Pseudognathodus homopunctatus*, *Vogelgnathus postcampbelli* and *Gnathodus* sp. 1.



SPECIFIC NAME	LOWER PART OF THE KO-YAMA LIMESTONE GROUP								
	TAKASE SECTION			HOYA SECTION					
	120212-22B	120212-22	120212-23	120601-05	120212-13	120212-11	120601-03	120212-06B	120212-05
	U. VISE.	U.VI – L.SE	U.VI – L.SE	U.VI – L.SE	L. SERP.	L. SERP.	U. BASH.	L. MOSC.	L. MOSC.
Gnathodus semiglaber Bishoff 1957	RW						RW		
Gnathodus praebilineatus Belka 2002b			■						
Gnathodus ex gr. *bilineatus* (Roundy 1926)		■		■					
Pseudognathodus homopunctatus (Ziegler 1962)			■				RW		
Lochriea ziegleri Nemyrovska, Perret & Meischner 1994					■				
Lochriea multinodosa (Wirth 1967)		■	■						
Lochriea commutata (Branson & Mehl 1941)				■					
Cavusgnathus unicornis Youngquist & Miller 1949				■					
Gnathodus ex gr. *bollandensis* Higgins & Bouckaert 1968					■				
Gnathodus girtyi girtyi Hass 1953 s.l. transition to *G. g. simplex* Dunn 1966					■				
Vogelgnathus campbelli (Rexroad 1957)					■				
Vogelgnathus postcampbelli (Austin & Husri 1974)							RW		
Gnathodus sp. 1							RW		
Lochriea nodosa (Bishoff 1957) s.l. transition to *L. cruciformis* (Clarke 1960)						■			
Idiognathodus primulus Higgins 1975							■		
Neoganthodus symmetricus (Lane 1967)							■		■
Idiognathodus craticulinodosus n. sp.							■		■
Idiognathodus sp. 3							■		
Streptognathodus expansus Igo & Koike 1964							■		
Gondolella clarki Koike 1967								■	■
Gondolella sp. 1									■
Idiognathoides sulcatus sulcatus Higgins & Bouckaert 1968									■
Idiognathoides macer (Wirth 1967)									■
Idiognathoides attenuatus (Harris & Hollingsworth 1933)									■
Idiognathoides convexus (Ellison & Graves 1941)									■
Idiognathodus delicatus Gunnell 1931 s.l.									■
Streptognathodus suberectus Dunn 1966									■
Neognathodus bothrops Merrill 1972									■

TEXT-FIGURE 7
List of conodonts from the lower part of the Ko-yama Limestone Group with compiled ranges. Massive: occurrence and range; RW: reworked occurrence.

***Idiognathoides convexus – Gondolella clarki* Zone**
Faunal composition: *Gondolella clarki*, *Gondolella* sp. 1, *Idiognathoides sulcatus sulcatus*, *Idiognathoides macer*, *Idiognathoides attenuatus*, *Idiognathoides convexus*, *Idiognathodus delicatus* s.l., *Streptognathodus suberectus*, *Neognathodus bothrops*, *Neoganthodus symmetricus* and *Idiognathodus craticulinodosus* n. sp.
Age: early Moscovian.

Conodont zones in the Akiyoshi Belt across the Mississippian – Pennsylvanian boundary

The conodont faunas from the lower part of the Ko-yama Limestone Group were studied with respect to the biostratigraphic reliance in “clastic carbonate” sediments. The existence of a conodont succession as well as its faunal stability was basically confirmed. The conodont faunal succession is: *Gnathodus semiglaber* (late Visean), *Gnathodus praebilineatus – Lochriea multinodosa* (late Visean), *Lochriea ziegleri – Gnathodus girtyi girtyi* s.l. (early Serpukhovian), *Neoganthodus symmetricus – Idiognathodus primulus* (middle – late Bashkirian) and *Idiognathoides convexus – Gondolella clarki* (early Moscovian) faunas.

In the Akiyoshi Belt, Koike (1967) subdivided the Atetsu Limestone into the seven assemblage zones of *Gnathodus bilineatus – G. texanus* (lower Chesterian), *G. bilineatus – G. commutatus nodosus* (middle Chesterian), *G. bilineatus – G. nodulifera* (upper Chesterian), *Gnathodus wapanuckensis* (lower Morrowan), *Idiognathodus parvus – Gnathodus nodulifera* (upper Morrowan), *Gondolella clarki – Polygnathodella ouachitensis* (lower Atokan), and *Idiognathodus delicates – Gnathodus atetsuensis* (upper Atokan) in ascending order.

In the lower part of the Akiyoshi Limestone, successive three of *Gnathodus bilineatus – Paragnathodus commutatus*, “S*pathognathodus campbelli*” and *Neognathodus bassleri symmetricus – Paragnathodus nagatoensis* conodont zones were proposed above the “*Cavusgnathus charactus* Fauna” in ascending order (Igo and Igo 1979). Among them, “S*pathognathodus campbelli*” Zone was set straddling on the Mississippian/Pennsylvanian boundary.

After Igo and Koike (1964), Watanabe (1975) reported *Gnathodus bilineatus – G. commutatus – G. nodosus* conodont fauna from the Omi Limestone, and he correlated it to “upper Visean” of *Gnathodus bilineatus – G. commutatus* Zone in the Atetu Limestone (Koike 1967) and in the Akiyoshi Limestone (Igo 1973). The biostratigraphic zonation were examined to subdivide into the seven of *Gnathodus bilineatus* (upper Visean), *Paragnathodus nodosus* (Namurian), *Idiognathoides noduliferus* (lower Bashkirian), *Neognathodus bassleri symmetricus* (middle Bashkirian), *Streptognathodus expansus* (upper Bashkirian – lower Moscovian), *Gondolella clarki* (lower Moscovian), *Idiognathodus delicates – Neognathodus roundyi* (upper Moscovian) zones in ascending order (Watanabe 1977 MS in Koike 1977).

Mizuno (1997) established successive six conodont zones of *Gnathodus bilineatus* (Serpkhovian), *Declinognathodus inaequalis – Gnathodus bilineatus* (lower Bashkirian), *Declinognathodus noduliferus* (lower Bashkirian), *Neolochriea nagatoensis* (middle Bashkirian),

STAGE This Study	AKIYOSHI BELT: Omi	Atetsu	Akiyoshi	Hina	Ko-yama	SUBSYSTEM
	Igo & Koike 1964; Watanabe 1975; *Watanabe 1977ms in Koike 1977	Koike 1967	Igo 1973; Igo & Igo 1979	Mizuno 1997	**Ishida et al. This Study**	
Gzhelian						PENNSYLVANIAN
Kasimovian						PENNSYLVANIAN
Moscovian	*Idiognathodus delicatus - Neognathodus roundyi* *Gondolella clarki*	*Idiognathosodus delicatus - Gnathodus atetsuensis* *Gondolella clarki - Polygnathodella ouachitensis*	*Neognathodus bothrops - Gnathodus kanumai - Idiognathoides opimus - Idiognathodus delicatus - Gondolella* sp.		*Idiognathoides convexus - Gondolella clarki*	PENNSYLVANIAN
Bashkirian	*Streptognathodus expansus - Gnathodus opimus* *Neognathodus bassleri symmetricus* *Idiognathoides noduliferus*	*Idiognathodus parvus - Gnathodus nodulifera* *Gnathodus wapanuckensis* *Gnathodus bilineatus - Gnathodus nodulifera*	*Neognathodus bassleri symmetricus - Paragnathodus nagatoensis* *"Spathognathodus campbelli"*	*Neognathodus symmetricus* *Neolochriea koikei* *Neolochriea nagatoensis* *Declinognathodus noduliferus*	*Neoganthodus symmetricus - Idiognathodus primulus*	PENNSYLVANIAN
Serpukhovian		*Gnathodus bilineatus - Gnathodus nodulifera*	*"Spathognathodus campbelli"*	*Declinognathodus inaequalis - Gnathodus bilineatus*	*Lochriea ziegleri - Gnathodus girtyi girtyi* s.l.	MISSISSIPPIAN
Visean	* *Paragnathodus nodosus (- Gn. bilineatus - Paragn. commutatus)* * *Gnathodus bilineatus*	*Gnathodus bilineatus - Gnathodus commutatus nodosus* *Gnathodus bilineatus - Gn. texanus*	*Gnathodus bilineatus - Paragnathodus commutatus* *"Cavusgnathus charactus fauna"*	*Gnathodus bilineatus*	*Gnathodus praebilineatus - Lochriea multinodosa* *Gnathodus semigrlaber*	MISSISSIPPIAN

TEXT-FIGURE 8
Carboniferous conodont zones in the Akiyoshi Belt, Japan. Watanabe 1977 ms: has been presented by Koike (1977) at the Pander Soc. Meeting.

Neolochriea koikei (middle Bashkirian), and *Neognathodus symmetricus* (upper Bashkirian) in the Hina Limestone.

After the above biostratigraphic research in the Akiyoshi Belt, the base of the Pennsylvanian subsystem was defined by the FAD of *Declinognathodus noduliferus* in the Arrow Canyon, Nevada (IUGS boundary; Lane et al. 1999), that coincides with the base of Bashkirian stage. And further, the Serpukhovian was proposed as the top stage of Mississippian, that the stage base was set at the FAD horizon of *Lochriea ziegleri* (Richards and Task Group 2007).

Therefore, the proposed conodont zonal correlation needs to revise in the Akiyoshi Belt based on the FAD of particular indices. Here tentatively proposed the revised correlation that was modified after the correlation by Mizuno (1997) with his zones in the Hina to those in the Akiyoshi (Igo 1973; Igo and Igo 1979), Atetsu (Koike 1967) and Omi (Igo and Koike 1964; Watanabe 1975; Watanabe 1977MS in Koike 1977), and the Mississippian/Pennsylvanian boundary was estimated based on the FAD of *Declinognathodus noduliferus* in those zones (text-fig. 8).

It is considerable that Koike (1967), reporting *Lochriea nodosa* from his *Gnathodus bilineatus – Gnathodus commutatus nodosus* (=*Lochriea nodosa*) Zone to the *Gnathodus bilineatus – G. nodulifera* (=*Declinognathodus noduliferus*) Zone in the Atetsu Limestone, attributed a late Visean to Bashkirian age to this *Gnathodus bilineatus – G. nodulifera* (=*Declinognathodus noduliferus*) Zone, possibly based on a mixed fauna.

Visean – Serpukhovian boundary in the Akiyoshi Belt

The base of the Serpukhovian was tentatively set at the FAD horizon of *Lochriea cruciformis* (326 Ma: Gradstein and Ogg 2004), later proposed to be set at the FAD horizon of *Lochriea ziegleri* on the *Lochriea nodosa – L. ziegleri* lineage (Richards and Task Group 2007). For Qi and Wang (2005), describing the conodont sequence from the upper Visean, Serpukhovian and the base of Bashkirian in South China, the first occurrence of *Lochriea ziegleri* and *Declinognathodus noduliferus* are considered as the bases of the Serpukhovian and Bashkirian, respectively.

In the bathyal Triollo cherty deep-water limestone of Cantabria (Spain), Nemyrovska (2005) distinguished the *Gnathodus praebilineatus, Gnathodus bilineatus* and *Lochriea nodosa* conodont zones in the Visean and the *Lochriea ziegleri* Zone in the early Serpukhovian, proposing the Visean/Serpukhovian boundary at the FAD of *L. ziegleri*. In Western Europe, Somerville (2008) refined the Late Early Carboniferous biostratigraphy in both deeper-water basins and shelf environments, establishing evolutionary lineages, in which *Gnathodus* and *Lochriea* are mentioned, the *L. ziegleri* FAD marking the Visean/Serpukhovian boundary. According to this *Lochriea nodosa – L. ziegleri* lineage, the FAD horizon of *Lochriea ziegleri* in the Hoya section (120212-13) marks the Visean/Serpukhovian boundary closest to the base of Serpukhovian. In the Arrow Canyon, Nevada (USA), the base of the Pennsylvanian subsystem which coincides with the base of Bashkirian stage, was defined by the FAD of *Declinognathodus noduliferus* (IUGS boundary; Lane et al. 1999).

Mizuno (1997) recognized six conodont zones in the Hina Limestone, puting the base of the *Declinognathodus inaequalis – Gnathodus bilineatus* Zone as the base of Pennsylvanian. In the Hina Limestone, the base of Bashkirian should be set at the base of *Declinognathodus noduliferus* Zone, as it is clear that Mizuno (1997) also defined the zonal base by the FAD of *Declinognathodus noduliferus*. The specimens from the Hina Limestone (Mizuno 1997: p. 248-249, figs. 12: 1-5) are also closely related to *Gnathodus girtyi girtyi* Hass s.l. transition to *G. girtyi simplex* Dunn by Nemyrovska (2005, p. 37, p. 84: pl. 7, figs. 16-20) from the *Lochriea ziegleri* Zone (Serpukhovian) of the Triollo section.

According to Mizuno (1997), a remarkable faunal turnover occurs from his *Declinognathodus inaequalis – Gnathodus bilineatus* Zone to the successive *Declinognathodus noduliferus* Zone in which Mississippian species disappear and new taxa including *Neolochriea* spp. appear before the appearance of *Neognathodus symmetricus*. As no *Neolochriea* fauna has yet been recognized in the study section of the lower part of the Ko-yama Limestone Group, this probably means that its bio-horizon is missing, as the result or in relation with the Serpukhovian/Bashkirian global eustatic low-stand (e.g. Hallam 1992; Nakazawa and Ueno 2009). Further relating to the Serpukhovian - Bashkirian eustatic low stand, it is suggestive that *Lochriea nodosa* was reported not only in the *Gnathodus bilineatus – G. commutatus nodosus* (=*Lochriea nodosa*) Zone but also in the *G. bilineatus – G. noduliferus* (=*Declinognathodus noduliferus*) Zone of the Atetsu Limestone (Koike 1967). The mixing of Serpukhovian and older elements (ex. *G. bilineatus* and *L. nodosa*) with the early Bashkirian fauna (*D. noduliferus* Zone) can be evaluated in the *G. bilineatus – G. noduliferus* Zone of Koike (1967).

Mixed fauna as early Bashkirian global eustatic low-stand

The reworked Serpukhovian and older elements appear in a particular clastic carbonate horizon that yields the middle – late Bashkirian *Neoganthodus symmetricus – Idiognathodus primulus* Fauna. After the early Bashkirian global eustatic low-stand (ex. Hallam 1992; Nakazawa and Ueno 2009), successive transgression might be considered as the erosional event that caused this middle – late Bashkirian clastic-carbonate resedimented with common association of basaltic pyroclasts shed from mid-oceanic atoll-type buildup into the chert-deposited slope-to-basin facies. In comparison to the underlying Visean – Serpukhovian part of the Ko-yama Limestone Group, the lithofacies above the middle – late Bashkirian shows signs of a deepening, such as the frequent association of spicular chert beds.

CONCLUSION

The Carboniferous part of the Ko-yama Limestone Group in the Akiyoshi Belt was studied for the conodont biostratigraphy with respect to the resolution in the clastic carbonate sedimentary field.

The obtained faunal succession of *Gnathodus semiglaber* (late Visean), *Gnathodus praebilineatus – Lochriea multinodosa* (late Visean), *Lochriea ziegleri*

– *Gnathodus girtyi girtyi* s.l. (early Serpukhovian), *Neoganthodus symmetricus* – *Idiognathodus primulus* (middle – late Bashkirian), and *Idiognathoides convexus* – *Gondolella clarki* (early Moscovian) was correlative with those of global stages respectively.

The FAD of *Lochriea ziegleri* marks the Visean/Serpukhovian boundary in the section.

Idiognathodus craticulinodosus n. sp. was described as the middle – late Bashkirian to early Moscovian index.

The middle – late Bashkirian *Neoganthodus symmetricus* – *Idiognathodus primulus* Fauna contains reworked Visean – Serpukhovian elements possibly related to an transgressive erosional event after the Early Bashkirian global eustatic low-stand.

The revision of conodont zonal correlation in the Akiyoshi Belt was examined with the Mississippian/Pennsylvanian boundary considering the FAD of *Declinognathodus noduliferus* in the previously proposed zones.

SYSTEMATIC PALEONTOLOGY

The specimens that we used for chronological purposes consisted of the conodont P_1 elements (text-fig. 7, plates 1, 2). The terminology of a particular part on the oral surface of P_1 element is consistent with the notaion of Purnell et al. (2000): anterior (= "ventral"), posterior (= "dosal") by the biological orientation, surrounded by quotation marks proposed in Sanz-Lopez et al. (2004: Figure 3). The occurrence of identified specimens was listed in text-fig. 7. The specific ranges were compiled mainly after Belka (1985), Blanco-Ferrera et al. (2005), Collinson et al. (1971), Dunn (1970b), Groves et al. (2003), Higgins (1975), Kullmann et al. (2008), Lane et al. (1971), Mizuno (1997), Nemyrovskaya (1999, 2005), Nikolaeva et al. (2009), Rhodes et al. (1971), Sanz-Lopez and Blanco-Ferrera (2012), Somerville (2008) and Sweet (1988). All the specimens were housed in the Laboratory of Geology, Institute of SAS, Tokushima University, Japan (Collection numbers: TKSU-CON-Specimen numbers).

Genus ***Cavusgnathus*** Harris and Hollingsworth 1933

Cavusgnathus HARRIS and HOLLINGS-WORTH 1933 p. 200-201.

Type species: *Cavusgnathus alta* Harris and Hollingsworth 1933

Cavusgnathus unicornis Youngquist and Miller 1949

Plate 1, figure 5

Cavusgnathus unicornis YOUNGQUIST and MILLER 1949, p. 619, pl. 101, figs.18-23. —— Rexroad 1958, p. 17, pl. I, figs. 6-11. —— KOIKE 1967, pp. 38-39, pl. 1, figs. 2, 3. —— WATANABE 1973, p. 163, pl. 15, figs. 1, 2, 4-6. —— LANE and STRAKA 1974, pp. 70-71. —— HIGGINS and VARKER 1982, p. 160, pl. 18, fig. 14. —— MIZUNO 1997, p. 251, figs. 11: 4a, 4b.

Specimens: 001061, 001058.

Remarks: *Cavusgnathodus unicornis* is distinctive from *C. charactus* and *C. convexus* by possessing high denticle on the posterior end of blade (Rhodes et al. 1969). The median carina is completely absent in this specimen that is usual in case of relatively younger small specimens of *C. unicornis*, and the deep V-shaped median longitudinal trough on the platform characterizes the species. We tentatively distinguish *C. unicornis* from *C. naviculus* that has inconspicuous carina along the posterior one-third of the central trough and nodular transverse ridge on the inner platform.

Occurrence: 120601-05 LS (packstone bed).

Age: late Visean (*Lochriea multinodosa* Zone).

Genus ***Gnathodus*** Pander 1856

Type species: *Polygnathus bilineatus* Roundy 1926

Remarks: *Gnathodus bilineatus* (Roundy 1926) was designated as type species of *Gnathodus* (Tubbs 1986), because of the missing of type specimens of *Gnathodus mosquensis* Pander 1856, and their type locality was uncertain

Gnathodus* ex gr. *bilineatus (Roundy 1926)

Plate 1, figures 3, 7

Gnathodus bilineatus (Roundy). —— KOIKE 1967, pp. 296, 317, pl. 1, figs. 9-11. —— RHODES et al. 1969, 94-95, pl. 18, figs. 14a-17d. —— WEBSTER 1969, pp. 30-31, 114-115, pl. 5, figs. 11, 12. —— LANE and STRAKA 1974, pp. 72-77, figs. 32: 1-5, 7, 9, 11-13; figs. 33: 11-13, 19-23, 25, 28-32; figs. 34: 10, 13-26; fig. 40: 27. —— WATANABE 1975, p. 163, pl. 14, figs. 1-5. —— Nakashima and Sano 2007, p. 347, figs. 16: 1-5.

Gnathodus bilineatus (Roundy) sub. sp. *bilineatus* HIGGINS and BOUCKAERT 1968, p. 29, pl. 3, fig. 9.

Gnathodus bilineatus bilineatus (Roundy). —— HIGGINS 1975, pl. 11, figs. 1-4, 6, 7. —— HIGGINS and WAGNER-GENTIS 1982, p. 330, pl. 34, figs. 1, 3. —— QI and WANG 2005, pl. 1, fig. 12. —— KULLMAN et al. 2008, pp. 646-647, fig. 10: 28.

Gnathodus bilineatus Roundy. —— METCALFE 1981, pl. 3, figs. 2a, b, 3a-c, 4a-d. —— MIZUNO 1997, pp. 250-251, figs. 11: 1-3. —— BLANCO-FERRERA, GARCIA-LOPEZ and SANZ-LOPEZ 2005, pp. 22-23, 24, figs. 6: 17-21.

Gnathodus bilineatus bilineatus Roundy. —— GARCIA-LOPEZ and SANZ-LOPEZ 2002a, pp. 160-161, pl. 2, fig. 18.

Gnathodus bilineatus spp. B. —— GARCIA-LOPEZ and SANZ-LOPEZ 2002b, pp. 202-203, pl. 4, fig. 12.

Gnathodus bilineatus spp. C. —— GARCIA-LOPEZ and SANZ-LOPEZ 2002b, pp. 202-203, pl. 4, fig. 13.

Gnathodus joseramoni SANS-LOPEZ, BLANCO-FERRERA and GARCIA-LOPEZ 2004, pp. 4-7, pl. 1, figs. 3-16; pl. 2, figs. 5-12; text-figs. 4: 5-14.

Gnathodus bilineatus remus Meischner and Nemyrovska 1999. —— NEMYROVSKA 2005, p. 33, Pl. 5, figs. 1, 8, 10, 12, 14.

Gnathodus postbilineatus Nigmadganov and Nemirovskaya 1992. —— SANZ-LOPEZ et al. 2006, pp. 8-9, Pl. 2, figs. 9-12. —— KULLMAN et al. 2008, pp. 646-647, fig. 10: 23.

Gnathodus ex gr. *bilineatus* (Roundy). —— KULLMAN et al. 2008, pp. 642-643, figs. 8: 7, 12, 21, 22; pp. 644-645, figs. 9: 10, 11, 19; pp. 646-647, figs. 10: 16, 20, 24, 27; pp. 648-649, figs. 11: 3, 6-9, 12, 14.

Specimens: 001059, 001062, 001067, 001072, 001071, 001072, 001234, 001192, 001193, 001198, 001208.

Remarks: This species is characterized by the development of nodular rows on the expanded inner platform. Figured pecimens (plate 1, figs 3, 7 from 120601-05 LS) have well-expanded inner platform, and the ridged parapet extends almost the end of platform along the carina. The carina is clearly separated from the parapet by the adcarinal trough. The ontogenetic morphological change appeared as laterally expanding of the inner platform and increasing of nodular ornamentation on it. The variations in adult forms were also recognized during its range from late Visean to Serpukhovian (e.g. Rhodes et al. 1969; Nemyrovska 2005). Herein, the species is widely defined, because the classification of *G.* ex gr. *bilineatus* has been examined by many researchers, and the different species were proposed as in the synonyms, but the specific ranges and their diagnostic criteria are still more or less overlapped.

Occurrence: 120212-22 LS (grainstone bed with crinoids and brachiopod shells); 120601-05 LS (packstone bed); 120601-03 LS (text-fig. 6: A, B; reworked, in the middle – late Bashkirian crinoid packstone).

Age: late Visean (*Lochriea multinodosa* Zone) – Serpukhovian.

Gnathodus* ex gr. *bollandensis Higgins and Bouckaert 1968

Plate 1, figures 4, 8, 9

Gnathodus bilineatus (Roundy) sub. sp. *bollandensis* HIGGINS and BOUCKAERT 1968, pp. 29-30, pl. 2, figs. 10, 13; pl. 3, figs. 4-8, 10.

Gnathodus bilineatus bollandensis Higgins and Bouckaert. —— HIGGINS 1975, pl. 11, figs. 5, 8-13. —— GARCIA-LOPEZ and SANZ-LOPEZ 2002b, pp. 202-203, pl. 4, fig. 16. —— QI and WANG 2005, pl. 1, fig. 3. —— SANZ-LOPEZ et al. 2006, p. 8, pl. 2, figs. 3-8.

Specimens: 001073, 001079, 001182, 001073, 001074, 001076, 001077, 001185, 001184.

Remarks: The species is characterized by a relatively narrow platform and the lack of posterior lateral row of nodes adjacent to the carina. The rows of nodes do not appear on the outer platform, because the nodes are weak, less number, do not fused and dispersed. Inevitably, lateral expansion of posterior carina by the fusion of lateral rows does not appear.

Occurrence: 120212-13 LS (crinoid packstone with basaltic pyroclastics).

Age: early Serpukhovian (*Lochriea ziegleri* – *Gnathodus girtyi girtyi* s.l. Zone).

Gnathodus girtyi girtyi Hass 1953 s.l. transition to *G. girtyi simplex* Dunn 1966

Plate 1, figures 13, 14

Gnathodus girtyi girtyi Hass, 1953 s.l. transition to *Gn. girtyi simplex* Dunn 1966. —— NEMYROVSKA 2005, p. 37, pl. 7, figs. 16-20.

Declinognathodus inaequalis (Higgins 1975). ——MIZUNO 1999, pp. 248-249, figs. 12: 1-5 (?).

Specimens: 001181, 001186.

Remarks: The species is characterized by bending of the anterior platform at the carina – blade juxtaposition. The relatively narrow asymmetric platform is lancet-shaped, projecting toward the posterior end. Outer parapet, shorter than inner one, ends before the posterior end of the platform. The inner parapet joins with the carina before the posterior end. Above properties are suggestive of the ancestry of *Declinognathodus*. A similar phylogenetic scheme has been proposed by Nemyrovska (2005), showing the transition to *Gnathodus girtyi simplex* Dunn 1966. This species is also considered to be an ancestral form of *Neognathodus,* because both sides of the carina are followed by nodose parapets, their margins being upturned almost directly from the edge of basal cup without smooth part on the platform. *Gnathodus girtyi pyrenaeus* (Kullmann et al. 2008: p. 642, fig. 8: 19) is similar to this specimen in having a bended carina with asymmetric platform, but differs from the former in having a longer and smooth outer platform that reaches almost the posterior end of the carina.

Occurrence: 120212-13 LS (crinoid packstone with basaltic pyroclastics).

Age: early Serpukhovian (*Lochriea ziegleri* – *Gnathodus girtyi girtyi* s.l. Zone); early Serpukhovian (*Lochriea ziegleri* Zone: Nemyrovska 2005).

Gnathodus praebilineatus Belka 1985 transitional from *Gn. semiglaber* Bischoff to *Gn.* ex gr. *bilineatus* (Roundy)

Plate 1, figures 2, 6

Gnathodus praebilineatus BELKA 1985, p. 39, pl. 7, fig. 8 (only). —— GARCIA-LOPEZ and SANZ-LOPEZ 2002b, pp. 202-203, pl. 4, figs. 8-9. —— SANZ-LOPEZ et al. 2004: pl. 2, figs. 2, 3 (partim). —— BLANCO-FERRERA et al. 2005, pp. 22-23, 24, figs. 6: 13; 6: 14. —— NEMYROVSKA 2005, pl. 4, figs. 1, 7, 11; pl. 5. figs. 3, 6.

Gnathodus praebilineatus Belka transitional to *Gnathodus bilineatus* (Roundy). —— MEISCHNER and NEMYROVSKA1999, p. 438, pl. 2, figures 1-3.

Specimens: 001051, 001052, 001053.

Remarks: Characteristic is the shorter inner parapet that is followed by a row of some nodes posteriorly (plate 1, fig. 2). On the expanded outer platform, small nodes are roughly arranged on subconcentrical rows, and fused to form arc ridges. In mature specimen, the rows of nodes are fused together with the posterior carina, and form the laterally expanded posterior carina (plate 1, fig. 6). The specimens (plate 1, figs. 2, 6 from 120212-23 LS) are closely related to *Gnathodus praebilineatus* Belka (Garcia-Lopez and Sanz-Lopez 2002b; Blanco-Ferrera et al. 2005) that has a short ridged parapet on the anterior half of the outer platform, in addition to the expanded posterior carina by the fusion of nodes after the parapet.

The obtained specimens are morphologically closely related to the specimen (Belka, 1985: p. 39, pl. 7, fig. 8) that the author remarked transitional specimens to its descendant, *Gnathodus bilineatus bilineatus*, as well as shown by Garcia-Lopez and Sanz-Lopez (2002b: pp. 202-203, pl. 4, figs. 8-9). Belka (1985) also mentioned that *G, praebilineatus* evolved most likely from *G. semiglaber* by the development of the inner parapet and simultaneously by reduction of the posterior blade to become simple. The character is intermediate from *Gnathodus semiglaber* to *Gnathodus* ex gr. *bilineatus*, suggesting that the species is part of a phylogenetic lineage between *G. semiglaber* to *G.* ex gr. *bilineatus*.

Sanz-Lopes et al. (2004) established a new species *Gnathodus joseramoni* (*G. praebilineatus* Zone – *G. bilineatus* Zone) defining the descendant form of *G. semiglaber* (*G. texanus* Zone). Both species are characterized by an expanded posterior carina on their posterior platform, whereas in *G. joseramoni,* the inner parapet on the anterior platform is slightly longer, followed by nodes on the posterior platfom.

Occurrence: 120212-23 LS (packstone beds).

Age: late Visean (*Gnathodus praebilineatus* – *Lochriea multinodosa* Zone).

Gnathodus semiglaber Bischoff 1957

Plate 1, figure 1; Plate 2, figure 1

Gnathodus bilineatus semiglaber BISCHOFF 1957, p. 22, pl. 3, figs. 1-10, 12, 14.

Gnathodus semiglaber (Bischoff 1957). —— BELKA 1985, p. 42, pl. 7, Fig. figs. 1-3.

Gnathodus semiglaber Bischoff. —— GEDIK 1974, pp. 13-14, pl. 7, figs. 16 a, b (?), 19. —— GARCIA-LOPEZ and SANZ-LOPEZ 2002a, p. 160, pl. 2, fig. 21. —— SANZ-LOPEZ et al. 2004, pl. 1, figs. 1, 2. —— BLANCO-FERRERA et al. 2005, pp. 22-23, 24, figs. 6: 25; 6: 26 (?). —— NEMYROVSKA 2005, pl. 6, figures 7, 10.

Specimens: 001049, 001197.

Remarks: The species was originally diagnosed as a subspecies of *G. bilineatus* in which the surface of the outer cup is ornamented with dispersed nodes. The species is characterized by possessing a short high-standing inner parapet on the anterior half of the asymmetric platform. The parapet, having several transverse ridges, is separated by an adcarinal trough from the carina. Posterior half of the carina is laterally expanded, and followed by a row of small nodes that is fused with the expanded posterior carina. Comparing with *Gnathodus praebilineatus*, *G. semiglaber* has a shorter inner parapet and few dispersed nodes on the smooth outer platatform. Meischner (1970) suggested the possibility of both lineages: *G. semiglaber* – *G. bilineatus* and *G. delicatus* – *G. bilineatus*. From our observations, the morphological similarity between the *G. semiglaber* and *G. praebilineatus* suggests rather the *G. semiglaber* – *G. bilineatus* lineage.

Occurrence: TAKASE 120212-22B BL (wackestone block in the basaltic pyroclasts); 120601-03 LS (reworked, in the middle – late Bashkirian crinoid packstone).

Age: late Visean (*Gnathodus semiglaber* Zone).

Gnathodus **sp. 1**

Plate 2, figure 2

Specimen: 001198.

Remarks: Small inner platform at posterior end (one third of total length of the carina-blade) and outer parapet occupying nearly half the total lengh.

Occurrence: 120601-03 LS (reworked in middle – late Bashkirian crinoid packstone).

Age: This species might be derived from late Visean – Serpukhovian horizons with *Gnathodus semiglaber* and *Pseudognathodus homopunctatus*.

Genus ***Gondolella*** Stauffer and Plummer 1932

Type species: *Gondolella elegantula* Stauffer and Plummer 1932, p. 42.

Gondolella clarki Koike 1967

Plate 2, figures 29, 30

Gondolella clarki KOIKE 1967, p. 45, pl. 2, figs. 1-6.

Neogondolella cf. *clarki* (Koike). —— MENDEZ and MENENDEZ-ALVAREZ 1981, p. 113, figs. 3: 3A, 3B.

Neogondolella clarki (Koike). —— SAVAGE and BARKELEY 1985, p. 1459, figs. 6: 1-12.

Specimens: 001089, 001214, 001083.

Remarks: Slender platform, widest just before the rounded posterior end, tapers toward the anterior without development of free blade. Posteriorly projected cusp is situated at the posterior end of carina that is not surrounded by the platform. Basal

keel is slightly arched in lateral view, and the posterior end is loop-shaped in aboral view. At several hundreds high-magnification, a polygonal dimple architecture on the oral surface of the platform common in Gondolellid P_1 elements is visible.
Occurrence: 120212-06B LS (micrite bed alternating with spiculite chert); 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus – Gondolella clarki* Zone).

***Gondolella* sp. 1**
Plate 2, figures 27, 28
Remarks: The fragments differ from *Gondolella clarki* in having well-expanded flat platform with low carina that is composed of isolated denticles in oral view. Basal keel is low and not arched.
Occurrence: 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus – Gondolella clarki* Zone).

Genus ***Idiognathodus*** Gunnell 1931
Type species: *Idiognathodus claviformis* Gunnell 1931.

Idiognathodus delicatus Gunnell 1931 s.l.
Plate 2, figure 18
Idiognathodus delicatus Gunnell. ── ELLISON 1941, pp. 128-129, 134-135, pl. 22, figs. 31-36. ── WEBSTER 1969, pp. 35-37, 116-117, pl. 6, figs. 6-12. ── LANE et al. 1971, pp. 400-401, pl. 1, fig. 27. ── GRAYSON 1984, p. 49, pl.1, figs.1, 2, (except 12); pl. 3, figs. 2, 5, 6, 21, 23, 25, (except 3); pl. 4, figs. 1, 6-8, 17, 24. ── GRUBBS 1984, pp. 69, 74, pl. 1, figs. 5-7. ── SAVAGE and BARKELEY 1985, pp. 1464-1465, figs. 8: 1-4.
Idiognathodus delicatus Gunnell, Sp element. –— BITTER 1972, p. 58, pl. 3, fig. 4 (?).
Idiognathodus delicatus s.l. Gunnell. ── HIGGINS 1975, p. 47, pl. 17, fig. 7; pl. 18, figs. 1-3, 7.
Idiognathodus delicatus Zhao. ── NAKASHIMA and SANO 2007, p. 343, fig. 15: 20.
Specimens: 001086, 001229.
Remarks: Both sides of the platform that is larger on the inner side encompass nodose accessory lobes. The carina that ends on the anterior platform is flanked on both sides by nodose rows. The posterior platform shows transverse ridges across its surface.
Occurrence: 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus – Gondolella clarki* Zone).

Idiognathodus craticulinodosus n. sp.
Plate 2, figures 10, 17
Idiognathodus sp. ── SANZ-LOPEZ and BLANCO-FERRERA 2012, p. 7, fig. 6: 22 (only).
Derivation of the name: Grid (*craticula*) -like arrangement of nodes on the posterior platform.
Type specimen: Holotype (001202), paratype (001088), Hoya, Ko-yama Limestone Group, Okayama Prefecture, Japan.
Specimens: 001088 (paratype), 001202 (holotype), 001209.
Diagnosis: Lancet-shaped subsymmetric unit; platform: two-thirds of total length with free blade, rows of nodes on platform arranged at the cross-points forming a grid by longitudinal and transverse lineation; carina on the platform: anterior one-third to a quarter.
Measurement: Total (platform) length / maximum width (micron meter): 769 (462) / 246 – 1380 (880) / 385.
Description: The platform is covered by rows of nodes that form grid-pattern on the posteror half by the arrangement both longitudinal and transverse lineations. The carina extends to the anterior one-third to a quarter of the platform. In the younger specimen (pl. 2, fig.10), a longitudinal row of nodes extends on each side of the platform, except for the anterior free blade, nearly one-thirds of the total length. In mature specimen (pl. 2, fig. 17), two or more longitudinal rows of nodes are recognized over most of the anterior platform. The lancet-shaped platform, widest at the anterior one-third of the platform, gradually tapers toward the posterior end. Lateral lobes scarcely develop, and are only recognized as a few small marginal nodes on the inner platform in the area of maximum width.
Comparison: A similar species, characterized by the development of a nodose texture on the platform, is *Idiognathodus klapperi* Lane and Straka (1974: pp. 80-81, figs. 42: 12-16) that has a more developed inner anterior lobe and a rounded posterior platform end, in addition to the radiate rows of nodes from the posterior end of the platform. Basal cavity expands almost same as the platform outline.
Occurrence: 120601-03 LS (crinoid packstone); 120212-05 LS (wackestone).
Age: middle – late Bashkirian to early Moscovian (*Neoganthodus symmetricus – Idiognathodus primulus* Zone and *Idiognathoides convexus – Gondolella clarki* Zone).

Idiognathodus primulus Higgins 1975
Plate 2, figures 5, 6
Idiognathodus primulus HIGGINS 1975, p. 47, pl. 18, figs. 10-13.
Idiognathodus antiquus Stauffer and Plummer. ── MENDEZ and MENENDEZ-ALVAREZ 1981, p. 113, fig. 3: 8.
Specimens: 001201, 001205, 001195, 001190.
Occurrence: 120601-03 LS (crinoid packstone: Serpukhovian elements were mixed).
Age: middle – late Bashkirian (*Neoganthodus symmetricus – Idiognathodus primulus* Zone).

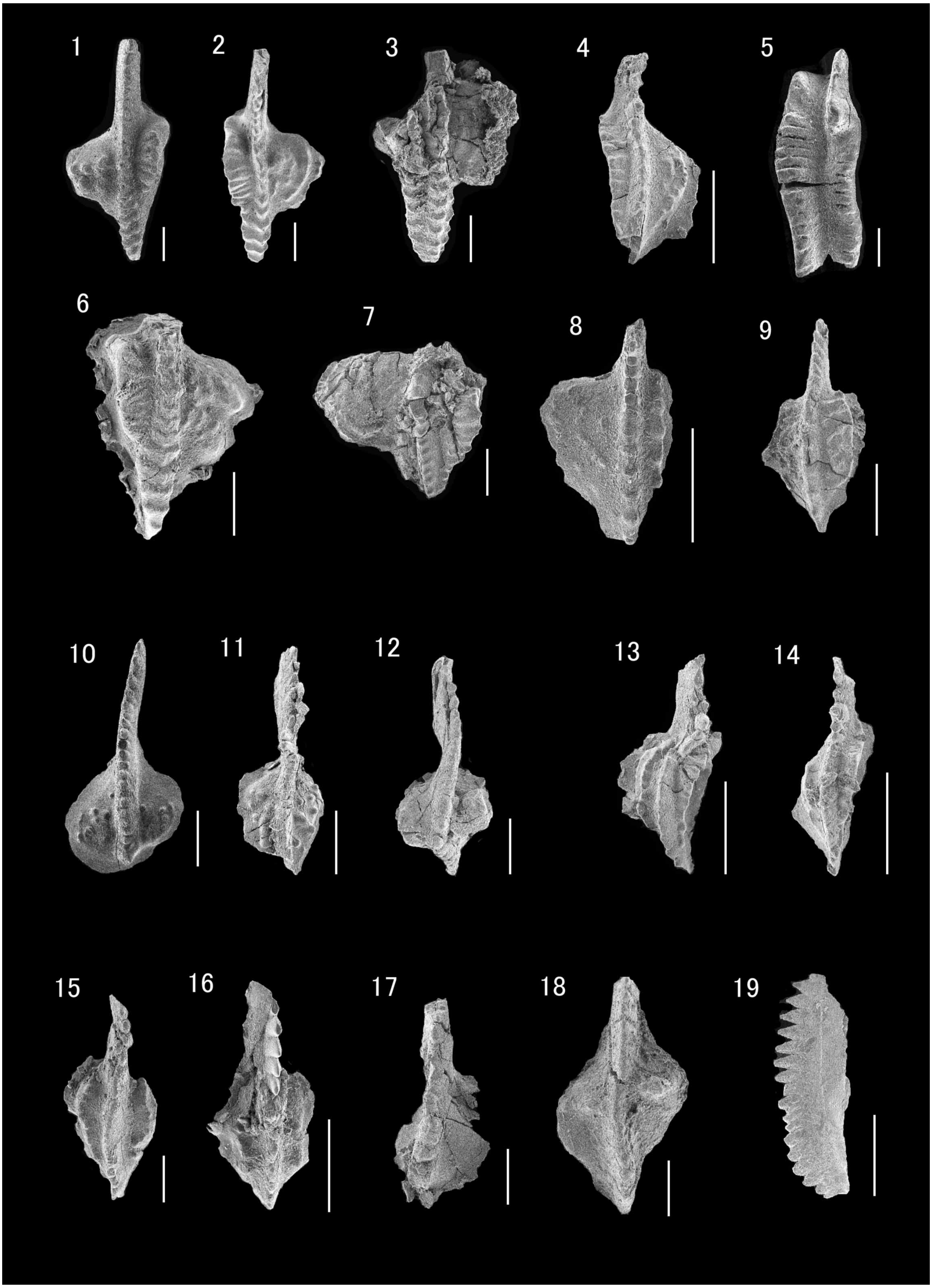

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PLATE 1

SEM-graphs of conodonts (P_1 elements) from the Ko-yama Limestone Group (Part 1). After the specific name and nomenclator(s), figures are explained: sample horizon, repository number, and condition of specimen. Except for the figure 19 in lateral view, figures are taken in oral view. All the specimens are housed in the Tokushima University SAS collection (repository No.: TKSU-CON-specimen number). All the scale bars indicate 200 micron meters.

1. *Gnathodus semiglaber* Bishoff 1957; TAKASE-120212-22B BL, TKSU-CON-001049 (reworked element extracted from the limestone brock in the basaltic pyroclastic breccia).
2. *Gnathodus praebilineatus* Belka 1985 (transitional from *G. semiglaber* to *G.* ex gr. *bilineatus*); TAKASE-120212-23 LS, TKSU-CON-001051.
3. *Gnathodus* ex gr. *bilineatus* (Roundy 1926); HOYA-120601-05 LS, TKSU-CON-001059.
4. *Gnathodus* ex gr. *bollandensis* Higgins and Bouckaert 1968; HOYA-120212-13 LS, TKSU-CON-001182.
5. *Cavusgnathus unicornis* Youngquist and Miller 1949; HOYA-120601-05 LS, TKSU-CON-001061.
6. *Gnathodus praebilineatus* Belka 1985 (transitional from *G. semiglaber* to *G.* ex gr. *bilineatus*); TAKASE-120212-23 LS, TKSU-CON-001052.
7. *Gnathodus* ex gr. *bilineatus* (Roundy 1926); HOYA-120601-05 LS, TKSU-CON-001062.
8. *Gnathodus* ex gr. *bollandensis* Higgins and Bouckaert 1968; HOYA-120212-13 LS, TKSU-CON-001073.
9. *Gnathodus* ex gr. *bollandensis* Higgins and Bouckaert 1968; HOYA-120212-13 LS, TKSU-CON-001079.
10. *Lochriea multinodosa* (Wirth 1967); TAKASE-120212-22 LS, TKSU-CON-001235.
11. *Lochriea multinodosa* (Wirth 1967); TAKASE-120212-23 LS, TKSU-CON-001055.
12. *Lochriea ziegleri* Nemyrovska, Perret and Meischner 1994; HOYA-120212-13 LS, TKSU-CON-001183.
13. *Gnathodus girtyi girtyi* Hass 1953 s.l. transition to *G. g. simplex* Dunn 1966; HOYA-120212-13 LS, TKSU-CON-001181.
14. *Gnathodus girtyi girtyi* Hass 1953 s.l. transition to *G. g. simplex* Dunn 1966; HOYA-120212-13 LS, TKSU-CON-001186.
15. *Pseudognathodus homopunctatus* (Ziegler 1962); TALKASE-120212-23 LS, TKSU-CON-001054.
16. *Pseudognathodus homopunctatus* (Ziegler 1962); TAKASE-120212-23 LS, TKSU-CON-001056.
17. *Lochriea commutata* (Branson and Mehl 1941); HOYA-120601-05 LS, TKSU-CON-001069.
18. *Lochriea nodosa* (Bishoff 1957) s.l. transition to *L. cruciformis* (Clarke 1960); HOYA120212-11 LS, TKSU-CON-001081.
19. *Vogelgnathus campbelli* (Rexroad 1957); HOYA-120212-13 LS, TKSU-CON-001180.

***Idiognathodus* sp. 3**
Plate 2, figure 9
Specimen: 001200.
Remarks: This species is closely related to *Idiognathodus incurvus* (Dunn 1966: p. 1031, pl. 158, figs. 2, 3; Blanco-Ferrera 2005: pp. 22-23, 25, figs. 6: 32-33.), *Idiognathodus sinuosis* Ellison and Graves 1941 in Lane and Straka (1974: pp. 81-82, figs. 37: 10-13, 21; figs. 42: 1-11; figs. 43: 1-8, 10-15, 1, 20) and the sinistral form species of *Idiognathodus humerus* (Dunn 1966: p. 1300, pl. 158, figs. 6, 7). The lateral lobe of this species, only scarcely developed as several small nodes on the inner platform margin, is more primitive than in related species.
Occurrence: 120601-03 LS (crinoid packstone with mixed Serpukhovian elements).
Age: middle – late Bashkirian (*Neoganthodus symmetricus – Idiognathodus primulus* Zone).

Genus *Idiognathoides* Harris and Hollingsworth 1933
Type species: *Idiognathoides sinuatus* Harris and Hollingsworth 1933

Idiognathoides attenuatus (Harris and Hollingsworth, 1933)
Plate 2, figure 25
Idiognathoides attenuatus (Harris and Hollingsworth). ── LANE and STRAKA 1974, fig. 41: 19. ── HIGGINS 1975, p. 48, pl. 15, fig. 1. ── MENDEZ and MENENDEZ-ALVALEZ1981, p. 113, fig. 3: 4. ── SANZ-LOPEZ and BLANCO-FERRERA 2012, p. 7, figs. 6: 15-20.
Specimens: 001228, 001095.
Remarks: This species is characterized by a flat platform surface that is covered by numerous straight and continuous transverse ridges. The platform is long, posteriorly tapered and usually widest near the anterior end. The short anterior median sulcus ends at the junction of the blade and platform.
Occurrence: 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus – Gondolella clarki* Zone).

Idiognathoides convexus (Ellison and Graves 1941)
Plate 2, figures 12, 19, 20
Idiognathoides convexus (Ellison and Graves). ── WEBSTER 1969, pp. 37, 114, 115, pl. 5, figs. 17, 18. ── DUNN 1970a, pp. 332, 334-335, pl. 63, fig. 20. ── LANE et al. 1971, pl. 1, figs. 18, 19. ── GRAYSON 1984, p. 50, pl.4, fig. 9 (partim). ── NAKASHIMA and SANO 2007, figs. 15: 2-4; 15: 7; 15: 11 (partim).
Idiognathoides pacificus SABAGE and BARKELEY 1985, p. 1467, figs. 9: 15, 23 (partim).
Specimens: 001085, 001094, 001098, 001087, 001093, 001097, 001215.

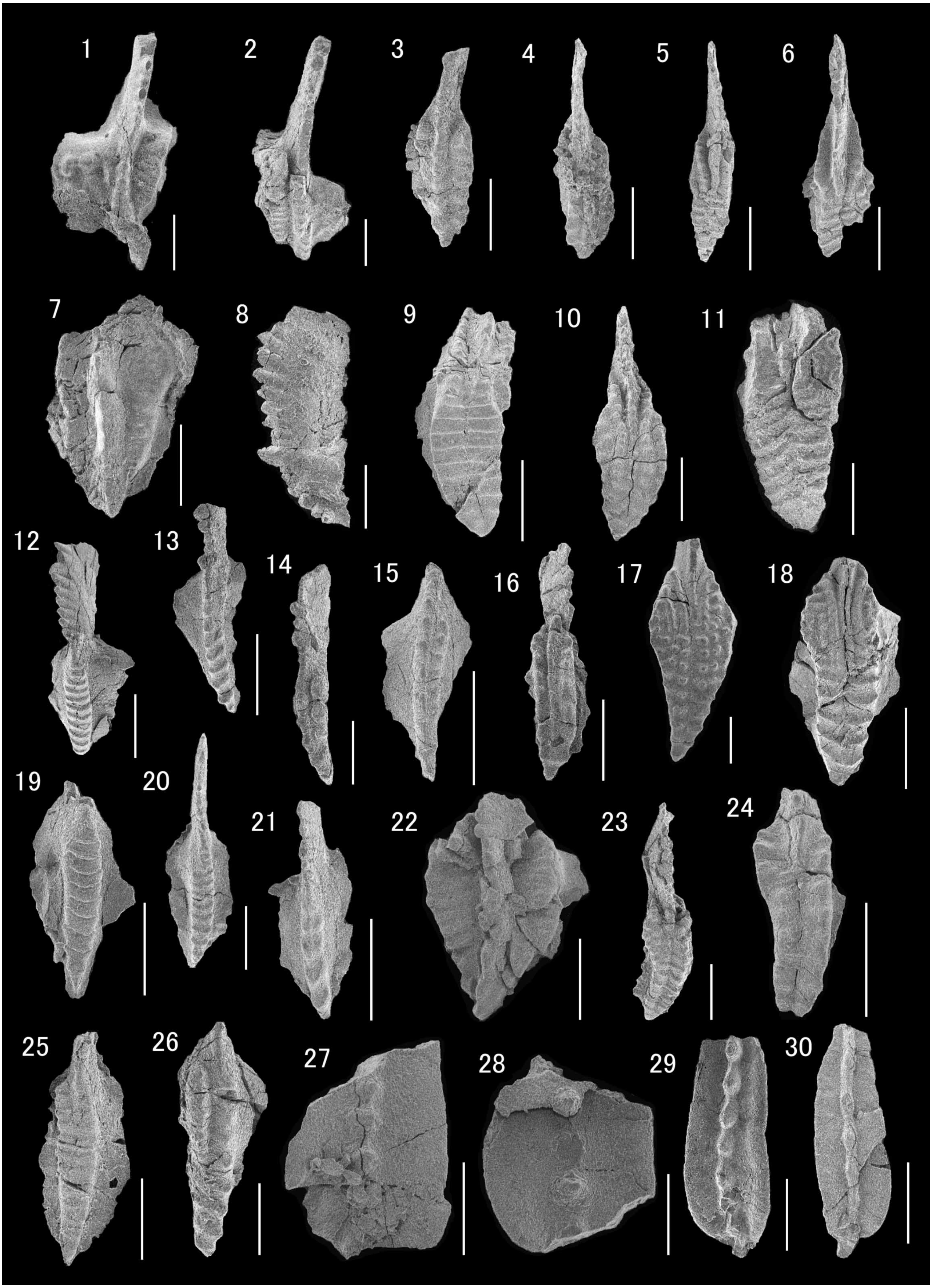
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PLATE 2

SEM-graphs of conodonts (P_1 elements) from the Ko-yama Limestone Group (Part 2). After the specific name and nomenclator(s), figures are explained: sample horizon, specimen number, and condition of specimen. Except for the figure 19 in lateral view, figures are taken in oral view. All the specimens are housed in the Tokushima University SAS collection (repository No.: TKSU-CON-specimen number). All the scale bars indicate 200 micron meters.

1. *Gnathodus semiglaber* Bishoff 1957; (reworked element from the lower horizon), HOYA-120601-03 LS, TKSU-CON-001197.
2. *Gnathodus* sp. 1; (reworked element from the lower horizon): HOYA-120601-03 LS, TKSU-CON-001198.
3. *Neoganthodus symmetricus* (Lane 1967); HOYA-120601-03 LS, TKSU-CON-001199.
4. *Neoganthodus symmetricus* (Lane 1967); HOYA-120601-03 LS, TKSU-CON-001207.
5. *Idiognathodus primulus* Higgins 1975; HOYA-120601-03 LS, TKSU-CON-001205.
6. *Idiognathodus primulus* Higgins 1975; HOYA-120601-03 LS, TKSU-CON-001201.
7. *Pseudognathodus homopunctatus* (Ziegler 1962);, HOYA-120601-03 LS, TKSU-CON-001196 (reworked element).
8. *Vogelgnathus postcampbelli* (Austin and Husri 1974); HOYA-120601-03 LS, TKSU-CON-001194 (reworked element).
9. *Idiognathodus* sp. 3; HOYA-120601-03 LS, TKSU-CON-001200.
10. *Idiognathodus craticulinodosus* n. sp.; HOYA-120601-03 LS, TKSU-CON-001202 (holotype).
11. *Streptognathodus expansus* Igo and Koike 1964; HOYA-120601-03 LS, TKSU-CON-001206.
12. *Idiognathoides convexus* (Ellison and Graves 1941); HOYA-120212-05 LS, TKSU-CON-001085.
13. *Idiognathoides sulcatus sulcatus* Higgins and Bouckaert 1968, HOYA-120212-05 LS, TKSU-CON-001101.
14. *Idiognathoides sulcatus sulcatus* Higgins and Bouckaert 1968; HOYA-120212-05 LS, TKSU-CON-001084.
15. *Idiognathoides sulcatus sulcatus* Higgins and Bouckaert 1968; HOYA-120212-05 LS, TKSU-CON-001218.
16. *Neoganthodus symmetricus* (Lane 1967); HOYA-120212-05 LS, TKSU-CON-001104.
17. *Idiognathodus craticulinodosus* n. sp.; HOYA-120212-05 LS, TKSU-CON-001088 (paratype).
18. *Idiognathodus delicatus* Gunnell 1931 s.l.; HOYA-120212-05 LS, TKSU-CON-001086.
19. *Idiognathoides convexus* (Ellison and Graves 1941); HOYA-120212-05 LS, TKSU-CON-001098.
20. *Idiognathoides convexus* (Ellison and Graves 1941); HOYA-120212-05 LS, TKSU-CON-001094.
21. *Idiognathoides sulcatus sulcatus* Higgins and Bouckaert 1968; HOYA-120212-05 LS, TKSU-CON-001220.
22. *Neognathodus bothrops* Merril 1972; HOYA-120212-05 LS, TKSU-CON-001210.
23. *Streptognathodus suberectus* Dunn 1966; HOYA-120212-05 LS, TKSU-CON-001102.
24. *Streptognathodus suberectus* Dunn 1966; HOYA-120212-05 LS, TKSU-CON-001211.
25. *Idiognathoides attenuatus* (Harris and Hollingthworth 1933); HOYA-120212-05 LS, TKSU-CON-001228.
26. *Idiognathoides macer* (Wirth 1967); HOYA-120212-05 LS, TKSU-CON-001092.
27. *Gondolella* sp. 1; HOYA-120212-05 LS, TKSU-CON-001225.
28. *Gondolella* sp. 1; HOYA-120212-05 LS, TKSU-CON-001106.
29. *Gondolella clarki* Koike 1969; HOYA-120212-05 LS, TKSU-CON-001089.
30. *Gondolella clarki* Koike 1969; HOYA-120212-05 LS, TKSU-CON-001214.

Remarks: This species is diagnostic in having a convex platform surface with numerous transverse ridges, also upward curving accurately the central part of the unit. The narrow platform tapers posteriorly. The short and shallow median sulcus extends as far as nearly the second transverse ridge on the anterior platform.
Occurrence: 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus* – *Gondolella clarki* Zone).

Idiognathoides macer (Wirth 1967)
Plate 2, figure 26
Idiognathoides macer (Wirth). ––– HIGGINS 1975, p. 49, pl. 10, figs. 10, 14, 15; pl. 13, fig. 17; pl. 16, fig. 1.
Idiognathoides convexus (Ellison and Graves). ––– NAKASHIMA and SANO 2007, fig. 15: 6 (only).
Specimens: 001092, 001099 (?).
Remarks: The platform architecture is composed of two parapets, separated by a median groove that extends over the anterior half of the platform. The outer parapet is continuous to the blade and consists of a row of nodes that reach the posterior end of the unit. The transversely ridged inner parapet extends over the anterior half of the platform. The posterior half of the platform has very narrow transverse ridges in a few variants.
Occurrence: 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus* – *Gondolella clarki* Zone).

Idiognathoides sulcatus sulcatus Higgins and Bouckaert 1968
Plate 2, figures 13, 14, 15, 21
Idiognathoides sulcatus sulcatus Higgins and Bouckaert. ––– HIGGINS 1975, pl. 13, figs. 11, 12, 16; pl. 15, fig. 15. ––– MENDEZ and MENENDEZ-ALVAREZ 1981, p. 113, fig. 3: 7. ––– NAKASHIMA and SANO 2007, fig. 15: 10.
Specimens: 001084, 001101, 001218, 001220, 001090, 001091, 001096, 001100, 001232, 001230, 001213, 001216, 001227, 001226, 001223, 001222, 001221, 001224.
Remarks: Diagnostic for this species is the platform that consists of two rows of nodose ridges. The two ridges are separated by a marked groove that almost extends to the posterior end.
Occurrence: 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus* – *Gondolella clarki* Zone).

Genus ***Lochriea*** Scott 1942
Type species: *Lochriea montanaensis* Scott 1942

Lochriea commutata (Branson and Mehl 1941)
Plate 1, figure 17
Spathognathodus commutatus BRANSON and MEHL 1941, p. 98, pl. 19, figs. 1-4.
Gnathodus commutatus commutatus (Branson and Mehl). ––– LANE and STRAKA 1974, pp. 77-78, figs. 37: 1-9; figs. 40: 15-18, 23-26.
Gnathodus commutatus (Branson and Mehl). ––– WATANABE 1975, p. 164, pl. 14, figs. 8-11.
Lochriea commutata (Branson and Mehl). ––– MIZUNO 1997, pp. 251, 253, figs. 11: 8-10. ––– GROVES et al. 2003, figs. 3: 1a-c, 8a-c. ––– BLANCO-FERRERA et al. 2005, pp. 21-23, figs. 6: 2-3. ––– NEMYROVSKA 2005, pp. 86-87, pl. 8, figs. 2, 7.
Specimen: 001069.
Remarks: The species has relatively expanded carina that bears more than seven node-like fused denticles. The transverse ridges appear between the fused denticles. The variability width of the median carina varies from a knife-like nodose ridge to a carina of broad nodes or short transverse ridges, down the median axis of the platform (Lane and Straka 1974).
Occurrence: 120601-05 LS (packstone bed).
Age: late Visean (*Gnathodus praebilineatus* – *Lochriea multinodosa* Zone).

Lochriea multinodosa (Wirth 1967)
Plate 1, figures 10, 11
Paragnathodus multinodosus (Wirth). ––– HIGGINS and WANGER-GENTIS 1982, p. 330, pl. 34, fig. 13 (only); figs. 12, 15 (transitional to *Lochriea ziegleri*).
Lochriea multinodosa (Wirth). ––– NEMYROVSKA 2005, p. 42, pl. 8, fig. 13. ––– QI and WANG 2005, p. 9, pl. 1, fig. 11. ––– NIKOLAEVA et al. 2009, fig. 6: N.
Lochriea nodosa (Bischoff). ––– NEMYROVSKA 2005, pp. 42-43, pl. 8, fig. 15 (only).
Pseudognathodus homopunctatus (Ziegler). ––– NIKOLAEVA et al. 2009, fig. 6: F (only).
Specimens: 001235, 001055.
Remarks: Diagnostic of this species is the presence of several small nodes on top of both the inner and outer hemispherical platforms.
Occurrence: 120212-22 LS (grainstone bed with crinoids and brachiopod shells), 120212-23 LS (packstone beds).
Age: late Visean (*Gnathodus praebilineatus* – *Lochriea multinodosa* Zone).

Lochriea nodosa (Bishoff 1957) s.l. transition to *L. cruciformis* (Clarke 1960)
Plate 1, figure 18
Gnathodus commutatus nodosus Bischoff. ––– KOIKE 1967, pp. 297, 317, pl. 1, fig. 19.
Gnathodus nodosus Bischoff. ––– RHODES et al. 1969, pp. 104-105, pl. 19, figs.17, 19 (partim). ––– WATANABE 1975, p. 164, pl. 14, fig. 14 (only).

Lochriea nodosa (Bischoff). ––– NEMYROVSKA 2005, pl. 8, fig. 17 (only). ––– KULLMANN et al. 2008, p. 642, fig. 8: 4; p. 644, fig. 9: 3; p. 646, figs. 10: 10; 10:17; 10: 22.
Specimens: 001081.
Remarks: The asymmetric inner and outer platforms are characteristic for this species. The maximum width of the inner platform is shifted anteriorly, whereas that of the outer platform is situated posteriorly. A large round to oval node is located on the widest and highest point of each platform. In oral view, these nodes form an oblique cross with the carina. In a specimen depicted in Koike (1967, pl. 1, fig. 19), these nodes are in asymmetric position on top of the outer and inner platforms.
Occurrence: 120212-11 LS (crinoid packstone with fine basaltic pyroclastics).
Age: early Serpukhovian (*Lochriea ziegleri – Gnathodus girtyi girtyi* s.l. Zone).

Lochriea ziegleri Nemyrovska, Perret and Meischner 1994

Plate 1, figure 12

Paragnathodus cruciformis (Clarke). ––– HIGGINS 1975, p. 71, pl. 7, fig.10 (only).

Paragnathodus nodosus (Bischoff). ––– HIGGINS 1975, p. 72, pl. 7, fig. 18 (only).

Lochriea ziegleri NEMYROVSKA, PERRET and MEISCHNER 1994, pp. 312-313, pl. 1, figs. 1-4, 6, 7, 11, 12; pl. 2, figs. 2, 11. ––– NEMYROVSKA 2005, p. 45, pl. 8, figs. 11, 14, 16. ––– QI and WANG 2005, p. 9, pl. 1, figs. 14, 17, 18. ––– KULLMANN 2008, p. 644, figs. 9: 18; 9: 21; 10.5 (partim). ––– NIKOLAEVA et al. 2009, figs. 6: A, B.
Specimen: 001183.
Remarks: The posterior platform margin forms a horse-hoof shaped ridge. Platform nodes are fused into the carina, forming ridges, a distinctive feature having bio-stratigraphic value for Higgins (1975). For Sommerville (2008), simmilar plausible phylogenetic scenario is in the transition from *L. nodosa* to *L. ziegleri*.
Occurrence: 120212-13 LS (crinoid packstone with basaltic pyroclastics).
Age: early Serpukhovian (*Lochriea ziegleri – Gnathodus girtyi girtyi* s.l. Zone).

Genus ***Neognathodus*** Dunn 1970a
Type species: *Polygnathus bassleri* Harris and Hollingsworth 1933

Neognathodus bothrops Merrill 1972

Plate 2, figure 22

Gnathodus cf. *roundyi* Gunnell. ––– KOIKE 1967, pp. 299-300, 317, pl. 1, figs. 27, 28.

Neognathodus bothrops MERRILL 1972, p. 823, pl. 1, figs. 8-15. ––– MENDEZ and MENENDEZ-ALVAREZ 1981, p. 113, fig. 3: 9. ––– GRAYSON 1984, pp. 52-53, pl.2, figs. 2: 14a, 14b, 15, 18, 20; pl. 3, figs. 17: 24a, 24b. ––– GRUBBS 1984, p. 71, pl. 3, figs. 1, 2, 5-9, 18, 20; pl. 3, figs. 17, 24a, 24b. ––– SAVAGE and BARKELEY 1985, pp. 1470-1471, figs. 11: 17-24.
Specimen: 001210.
Remarks: This species is characterized by its subsymmetrically expanded inner and outer platforms of an oval leaf-shaped total outline and both inner and outer platform margins elevated to form parapets. Prominent transverse ridges develop on the parapets. The carina, being composed of fused nodular denticles, extends to the posterior tip. In aboral view, lenticular to oval basal cavity extends almost full length of the platform.
Occurrence: 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus – Gondolella clarki* Zone).

Neoganthodus symmetricus (Lane 1967)

Plate 2, figures 3, 4, 16

Gnathodus bassleri symmetricus LANE 1967, p. 935, pl. 120, figs.2, 13, 14, 17; pl. 121, figs. 6, 9. ––– LANE et al. 1971, pl. 1, figs. 7, 8.

Gnathodus wapanuckensis (Harlton). ––– KOIKE 1967, p. 300, pl. 1, figs. 22-25.

Neognathodus bassleri symmetricus (Lane). ––– LANE and STRAKA 1974, p. 96, figs. 37: 22, 31, 32, 37-39; figs. 39: 16-18, 21-24.

Neognathodus symmetricus (Lane). ––– GRAYSON 1984, p. 51, pl. 2, fig. 7. ––– MIZUNO 1997, p. 252, figs. 12: 13-14.

Idiognathodus sinuosis Ellison and Graves. ––– NAKASHIMA and SANO 2007, fig. 15: 14 (only).

Neoganthodus symmetricus Lane.––– SANS-LOPEZ and BLANCO-FERRERA 2012, p. 7, fig. 6: 22 (only).
Specimens: 001104, 001199, 001207.
Remarks: The slender symmetric platform is composed of inner and outer parapets that have nodular ridges. The carina, built of nodular denticles, extends down to the end of the platform.
Occurrence: 120601-03 LS (crinoid packstone: Serpukhovian elements were mixed); 120212-05 LS (wackestone).
Age: middle – late Bashkirian to early Moscovian (*Neoganthodus symmetricus – Idiognathodus primulus* Zone and *Idiognathoides convexus – Gondolella clarki* Zone).

Genus ***Pseudognathodus*** Park 1983
Type species: *Gnathodus commutatus homopunctatus* Ziegler 1960, p. 39, pl. 4, fig. 3.

Pseudognathodus homopunctatus (Ziegler 1960)

Plate 1, figures 15, 16; Plate 2, figure 7

Gnathodus homopunctatus Ziegler. ––– HIGGINS 1975, pp. 33-34, pl. 7, figs. 1-6; pl. 10, fig. 7.

Pseudognathodus homopunctatus (Ziegler). —– PARK 1983, pp. 132-135, pl. 4, figs. 27-33. —– GROVES et al. 2003, figs. 3: 5a-c. —– BLANCO-FERRERA et al. 2005, pp. 22-23, 25, fig. 6: 31. —– NEMYROVSKA 2005, pp. 45-46, pl. 7, figs.2. 3.
Specimens: 001054, 001056, 001196.
Remarks: The subhexagonal platform, trapezoidal in transversal section, is surrounded by a marginal rim. Lateral margins, on both sides of the platform, are ridged with small nodes.
Age: late Visean (*Gnathodus praebilineatus – Lochriea multinodosa* Zone).

Genus ***Streptognathodus*** Stauffer and Plummer 1932
Type species: *Streptognathodus excelsus* Stauffer and Plummer 1932

Streptognathodus expansus Igo and Koike 1964
Plate 2, figure 11
Streptognathodus expansus IGO and KOIKE 1964, p. 189, pl. 28, fig. 14. —– KOIKE 1967, p. 318, pl. 3, figs. 6-8, 16, 17. —– WEBSTER 1969, pp. 46-47, 116-117, pl. 6, figs. 1-5. —– DUNN 1970a, pp. 316-317, 339-340, pl. 62, figs. 18-20; text-fig. 9G. —– LANE et al. 1971, pp. 400-401, pl. 1, fig. 20. —– LANE and STRAKA 1974, pp. 102-103, figs. 43: 9, 16-18, 21-26. —– NAKASHIMA and SANO 2007, p. 347, fig. 15: 15.
Idiognathodus togashii IGO and KOIKE 1964, p. 188, pl. 28, figs. 1-4 (juveniles).
Idiognathodus expunsus (Igo and Koike). —– GRAYSON 1984, pp. 51, 62, pl. 4, fig. 18
Specimen: 001206.
Remarks: Single rows of nodes appear on both sides of the anterior platform. The generic criteria of *Streptognathodus* consist clearly in its blade and extension of a short carina that ends on the anterior platform. A shallow longitudinal median trough separates the inner from the outer platforms. Numerous slightly curved transversal ridges form the herringbone pattern ornamenting both sides of the platform.
Occurrence: 120601-03 LS (crinoid packstone: mixed with reworked Serpukhovian elements).
Age: middle – late Bashkirian (*Neoganthodus symmetricus – Idiognathodus primulus* Zone).

Streptognathodus suberectus Dunn 1966
Plate 2, figures 23, 24
Streptognathodus suberectus DUNN 1966, p. 1303, pl. 157, figs. 4, 5, 6. 10. —– DUNN 1970a, pp. 333, 340, pl. 64, figs. 5-7; text-fig. 9H. —– DUNN 1970b, pp. 2970-2971, fig. 4. —– NAKASHIMA and SANO 2007, p. 347, fig. 15: 16.
Streptognathodus sp. A. —– KOIKE 1967, pp. 312, 318, pl. 3, fig. 18.
Specimens: 001102, 001211.
Remarks: The slender curved asymmetric platform, with nodose transverse ridges on both sides of the longitudinal trough, has only one lateral lobe on the inner anterior side of the platform that consists of several nodes in a row.
Occurrence: 120212-05 LS (wackestone).
Age: early Moscovian (*Idiognathoides convexus – Gondolella clarki* Zone).

Genus ***Vogelgnathus*** Norby and Rexroad 1985
Vogelgnathus Norby and Rexroad 1985, pp. 2-3
Type species: *Spathognathodus campbelli* Rexroad 1957

Vogelgnathus campbelli (Rexroad 1957)
Plate 1, figure 19
Spathognathodus campbelli Rexroad. —– KOIKE 1967, p. 310 (54), pl. 3, figs. 28, 30, 31, 33, 34 (partim).
Vogelgnathus campbelli (Rexroad). —– MIZUNO 1997, fig. 11: 7. —– NAKASHIMA and SANO 2007, p. 348, figs. 16: 13; 16:14.
Vogelgnathus campbelli Rexroad. —– NEMYROVSKA 2005, pp. 46-47, 72-73, pl. 1, figs. 1, 4 (partim).
Vogelgnathus campbelli Norby and Rexroad. –— KULLMANN et al. 2008, p. 642, figs. 8: 1, 3.
Specimens: 001180, 001179, 001187.
Remarks: The P_1 element carminiscaphate blade possesses nearly twenty almost equal sized denticles, cusp included. A weak lateral line is present on the anterior process, in lateral view. The narrow lenticular cavity occupies the entire posterior half of the aboral side. The height-length ratio of this mature specimen is less than one-third.
Occurrence: 120212-13 LS (crinoid packstone with basaltic pyroclastics).
Age: early Serpukhovian (*Lochriea ziegleri – Gnathodus girtyi girtyi* s.l. Zone).

Vogelgnathus postcampbelli (Austin and Husri 1974)
Plate 2, figure 8
Spathognathodus campbelli Rexroad. —– KOIKE 1967, p. 310 (54), pl. 3, fig. 27 (only). —– WATANABE 1975, pp. 166-167, pl. 15, figs. 12, 13 (partim).
Vogelgnathus akiyoshiensis (Igo). —– MIZUNO 1997, fig. 11: 6.
Vogelgnathus campbelli Rexroad. —– NEMYROVSKA 2005, pp. 46-47, 72-73, pl. 1, figs. 2, 5, 9 (partim).
Vogelgnathus postcampbelli (Austin and Husri). —– NEMYROVSKA 2005, pp. 46-47, 72-73, pl. 1, figs. 3, 7, 10.
Specimen: 001194.
Remarks: This species is distinguishable from *V. campbelli* by a large projected cusp at the junction of anterior and posterior processes on the lenticular

basal cup. Dominating the anterior one-third to one-forth of the blade, the five denticles of the posterior process abruptly decrease in height posteriorly.
Occurrence: 120601-03 LS (reworked in middle – late Bashkirian crinoid packstone).
Age: supposed to be late Visean to Serpukhovian (reworked together with *Gnathodus semiglaber* and *Pseudognathodus homopunctatus*).

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