

Uppermost Silurian to Lower Devonian radiolarians from the Hitoegane area of the Hida-gaien terrane, central Japan

Toshiyuki Kurihara

Graduate School of Science and Technology, Niigata University, Niigata 950-2181, Japan
email: tosiyuki@rj8.so-net.ne.jp

ABSTRACT: Two distinctive uppermost Silurian to Lower Devonian radiolarian assemblages, the *Pseudospongoprimum tauversi* Assemblage and the *Futobari solidus-Zadrappolus tenuis* Assemblage, occur in new localities of felsic tuffaceous strata in the Hitoegane area of the Hida-gaien terrane of central Japan. The first is characterized by the presence of *P. tauversi* and diverse inaniguttids, which can be correlated with the well-constrained Pridolian radiolarian zonal fauna defined in west Texas. The second occurs stratigraphically above beds containing the *P. tauversi* Assemblage and in strata correlative to beds from which a probably Lower Devonian flora has been recovered. These occurrences indicate that the *F. solidus-Z. tenuis* Assemblage ranges from uppermost Silurian to Lower Devonian. Based on the stratigraphic context for the underlying Pridolian *P. tauversi* Assemblage, the probably Lower Devonian flora, and the reinterpretation of the previously dated zircon U/Pb age, the *F. solidus-Z. tenuis* Assemblage is the first confirmed radiolarian assemblage from the lowermost Devonian. Previous workers have suggested that entactiniid radiolarians became increasingly dominant in the latest Silurian to Early Devonian, but the present study shows that inaniguttids such as *Futobari* and *Zadrappolus* were dominant in the early to probably middle Early Devonian. A new inaniguttid species is described: *Zadrappolus* (?) *nudus* n. sp.

INTRODUCTION

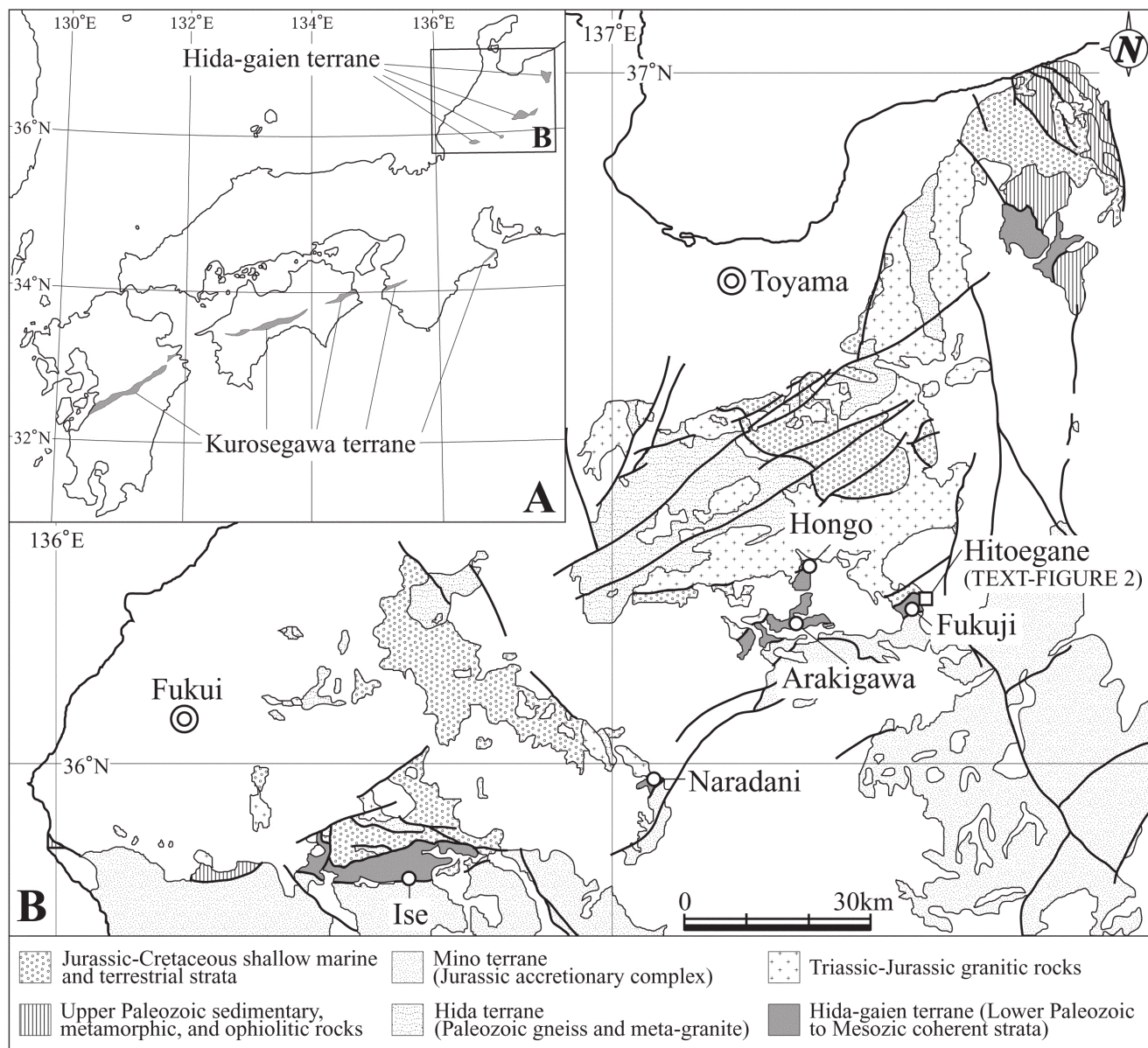
The current radiolarian biostratigraphic scheme for the Middle Paleozoic in Japan was developed by Furutani (1990) and Wakamatsu et al. (1990), based upon studies of tuffaceous strata in the Hida-gaien and Kurosegawa terranes (text-figure 1). Furutani (1990) reported five Silurian to Devonian (?) radiolarian assemblages from the Fukuji-Hitoegane area in the Hida-gaien terrane and described 28 species, including 21 new species. However, since outcrops are generally poor, most information on radiolarian assemblages has come from spot localities. In addition, the availability of only sparse radiolarian data in the early 1990s, along with poor chronostratigraphic control, have hampered age assignments.

In the past decade, studies of Upper Silurian radiolarians in North America, the Urals and Japan have made significant advances in establishing biostratigraphic zonations (Noble 1994; Amon et al. 1995; Umeda 1998; Noble and Aitchison 2000). In contrast, despite increasing knowledge about radiolarian faunas overall (Stratford and Aitchison 1997; Umeda 1998; Aitchison et al. 1999; Kurihara and Sashida 2000a), uppermost Silurian to Lower Devonian biozonations are still poorly established. Noble and Aitchison (2000) proposed the Entactiniid Superzone for the Devonian, but this long-ranging biozone (Lower and Middle Devonian to Upper Devonian) has limited usefulness for age determination. Therefore, at the present stage, further biostratigraphic work is needed to refine the zonation for this time period and to calibrate more precise ages. In this study, the Middle Paleozoic radiolarian biostratigraphy of the Hida-gaien terrane is reinvestigated in order to establish a useful biozonation and to understand the geologic evolution of this terrane. Here I focus on biostratigraphic results in the Hitoegane area of the Hida-gaien terrane, and report the first confirmed uppermost Silurian to Lower Devonian radiolarian assemblage overlying an uppermost Silurian assemblage.

REGIONAL GEOLOGIC AND STRATIGRAPHIC FRAMEWORK

The Hida-gaien terrane is composed largely of Ordovician to Cretaceous (?) sedimentary and volcanic rocks along with ultramafic rocks and crystalline schist. This terrane occurs in a narrow zone between the Hida terrane, comprised of Paleozoic gneiss and meta-granite, and the Mino terrane consisting of a Jurassic accretionary complex. Lower and Middle Paleozoic rocks are exposed well in the following four areas: Fukuji-Hitoegane, Hongo-Arakigawa, Naradani, and Ise (text-figure 1). The Ordovician to Silurian rocks are represented by tuffaceous turbidite sequences of deep-water origin. Although the Devonian rocks were believed to be shallow-marine carbonates (e.g., Igo 1990), recent biostratigraphic studies clearly show the widespread occurrence of tuffaceous clastic rocks (Tazawa et al. 2000; Kurihara and Sashida 2000a; Kurihara 2003).

The Hitoegane area is located in the central part of the Hida-gaien terrane (text-figure 1), where a number of important geological and paleontological investigations have been conducted (e.g., Tsukada and Koike 1997). Paleozoic rocks in this area consist of basaltic pyroclastic rocks and pillow lava, overlain by felsic tuffaceous rocks. The basal unit has been defined as the Iwatsubodani Formation (Tsukada 1997). The overlying unit was first defined as the Yoshiki Formation (Igo et al. 1980), and was then redefined as the Hitoegane Formation (Harayama 1990; Tsukada 1997) (text-figures 2, 3). Recent paleontological works have shown that the Hitoegane Formation ranges from Middle or Upper Ordovician through probably Lower Devonian, based on conodonts, trilobites, and plant fossils (Kobayashi and Hamada 1987; Igo 1990; Tazawa and Kaneko 1991; Tsukada and Koike 1997). Although no age control exists for the Iwatsubodani Formation, it is considered to be pre-Middle Ordovician on the basis of its stratigraphic relationship to the overlying Hitoegane Formation (Tsukada 1997). The rocks on the northern margin of the Hitoegane area are structurally com-



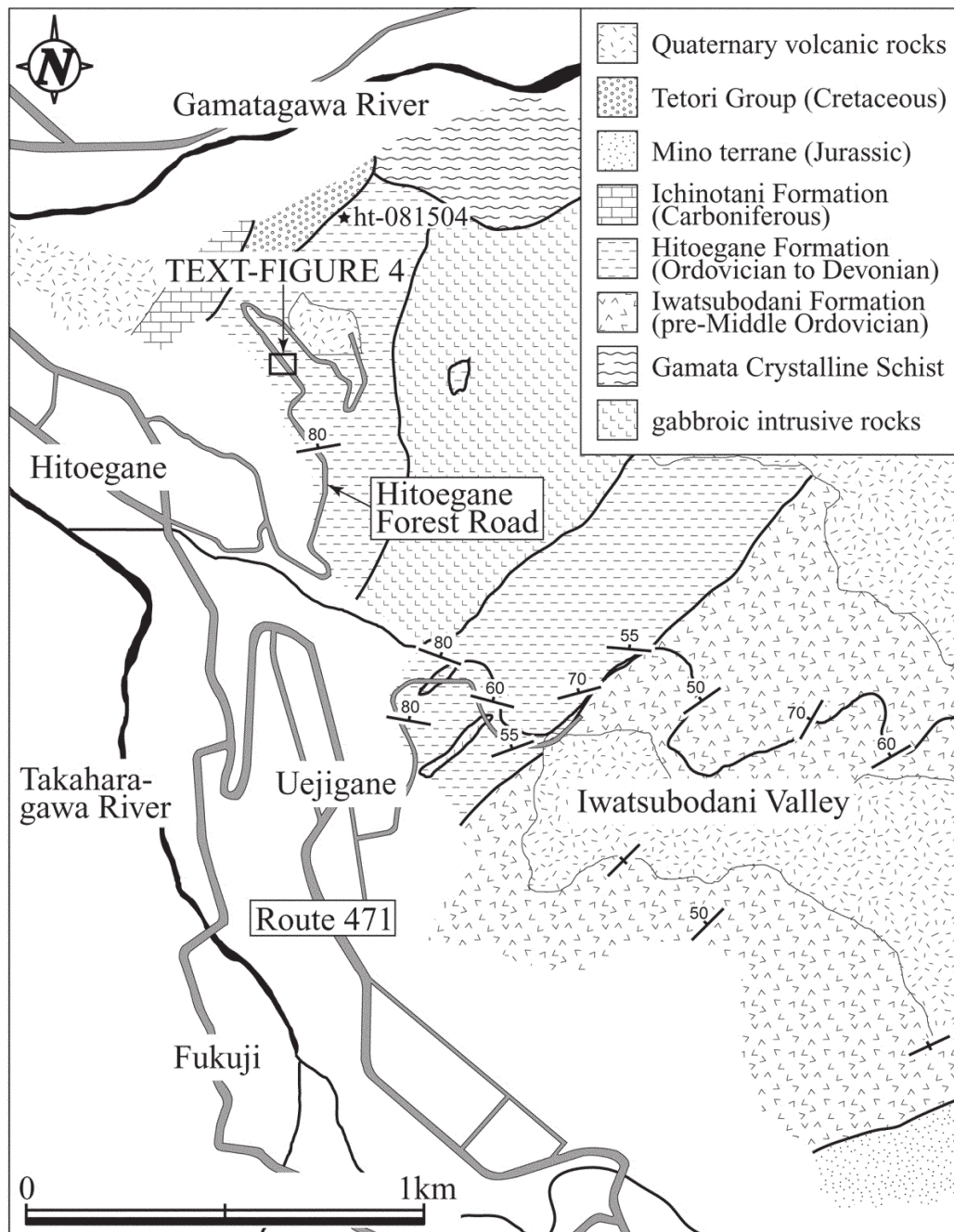
TEXT-FIGURE 1

Index map. A: Index map showing the Hida-gaien and Kurosegawa terranes. B: Simplified geologic map of the Hida-gaien and adjacent terranes.

plex and consist of Carboniferous carbonate rocks (Ichinotani Formation), Cretaceous clastic rocks (Tetori Group), and crystalline schists of unknown age (Gamata Crystalline Schist). Gabbroic rocks intrude extensively into the Hitoegane Formation and the Gamata Crystalline Schist (text-figure 2).

The Hitoegane Formation crops out east of Uejigane and Hitoegane, and along the left bank of the Gamatagawa River (text-figure 2). In general, strata of this formation strike east-west or northeast-southwest, dip steeply to the north or northwest, and can be subdivided into lower and upper parts (text-figure 3). The total thickness of this formation is over 800 meters (Tsukada 1997). The lower part of this formation, typically exposed along the Iwatsubodani Valley, consists of felsic tuff, tuffaceous sandstone, tuffaceous mudstone, and alterna-

tions of these lithologies containing frequent intercalations of basaltic volcanoclastic rocks. The Middle to Upper Ordovician (Llanvirnian to Caradocian) conodont *Periodon aculeatus* Hadding has been reported by Tsukada and Koike (1997) from thinly alternating beds of felsic tuff and tuffaceous mudstone. Radiolarian tests are commonly richly abundant within the fine-grained felsic tuffaceous rocks, but are highly recrystallized. The upper part of this formation seems to be widely exposed to the east of Hitoegane and along the left bank of the Gamatagawa River, but outcrops can be found only at a few isolated localities, due to the presence of soil and Quaternary volcanic rock cover. The upper part of this formation has a similar lithology to the lower part, except for the absence of intercalations of basaltic volcanoclastic rocks. Moderately well-preserved radiolarians are common in the fine-grained portion of



TEXT-FIGURE 2

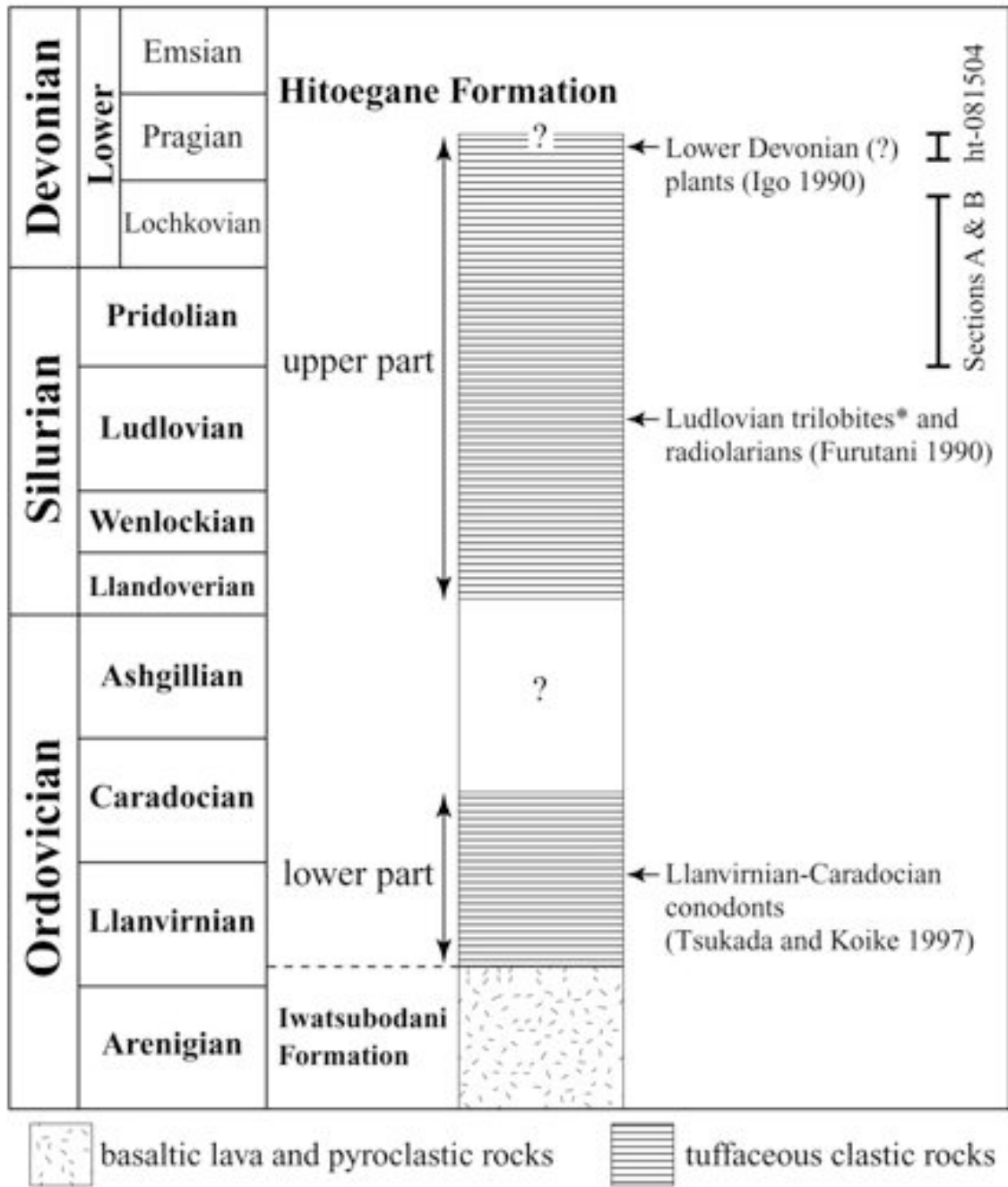
Geologic map of the Hitoegane area in the Hida-gaien terrane, showing study sections and a radiolarian sample locality (ht-081504).

the alternating tuffaceous sandstone and mudstone. The felsic tuff and tuffaceous mudstone contain rare trilobites and plant fossils, which constrain the upper part of this formation to lowermost Upper Silurian to probably Lower Devonian. Kobayashi and Hamada (1987) and Tazawa and Kaneko (1991) reported *Encrinurus* sp. cf. *E. kitakamiensis* Kobayashi and Hamada and *Encrinurus* sp. cf. *E. fimbriatus* Kobayashi and Hamada, respectively. Trilobite-bearing strata were assigned to the middle to upper or upper Ludlovian. Igo (1990) reported primitive land-plant fossils from the left bank of the Gamatagawa River, which corresponds to the uppermost part of this formation. He

suggested that the plant specimen is similar to a certain kind of zosterophyll species which is common in the Lower Devonian of South China, but he did not identify the species name or show any figure of it.

PREVIOUS RADIOLARIAN STUDIES

Radiolarians in the Hitoegane area were investigated by Furutani (1990), who figured and listed more than nine species from a total of 11 horizons (samples H-1 to 11 in Furutani 1990) within the upper part of the Hitoegane Formation, including: *Zadrap-*



TEXT-FIGURE 3
Generalized stratigraphy of Lower to Middle Paleozoic rocks in the Hitoegane area. Studied interval is indicated to the right of the column. Ludlovian trilobites (asterisk) were reported by Kobayashi and Hamada (1987) and Tazawa and Kaneko (1991).

polus spinosus Furutani, *Zadrappolus* (?) *hitoeganensis* Furutani, *Spongocoelia parvus* Furutani, *Spongocoelia kamitakarensis* Furutani, *Futobari morishitai* Furutani, *Stylosphaera* (?) sp. A, *Stylosphaera* (?) sp. B, *Secuicollacta vulgaris* Furutani, and *Secuicollacta* spp. He recognized two assemblages for these species, based on faunal composition: the *Spongocoelia parvus*-*Spongocoelia kamitakarensis* Assemblage and the *Stylosphaera* (?) sp. A-*Stylosphaera* (?) sp. B Assemblage. The former recovered from samples H-1 and H-7 to 11 contains *Z. spinosus*, *Z. (?) hitoeganensis*, and *S. vulgaris*, to-

gether with the nominative species. The latter assemblage, obtained from sample H-3, has a very low diversity and does not contain other species. Radiolarians from the other samples (H-2, H-4 to 6) were poorly preserved and Furutani (1990) did not mention their faunal details.

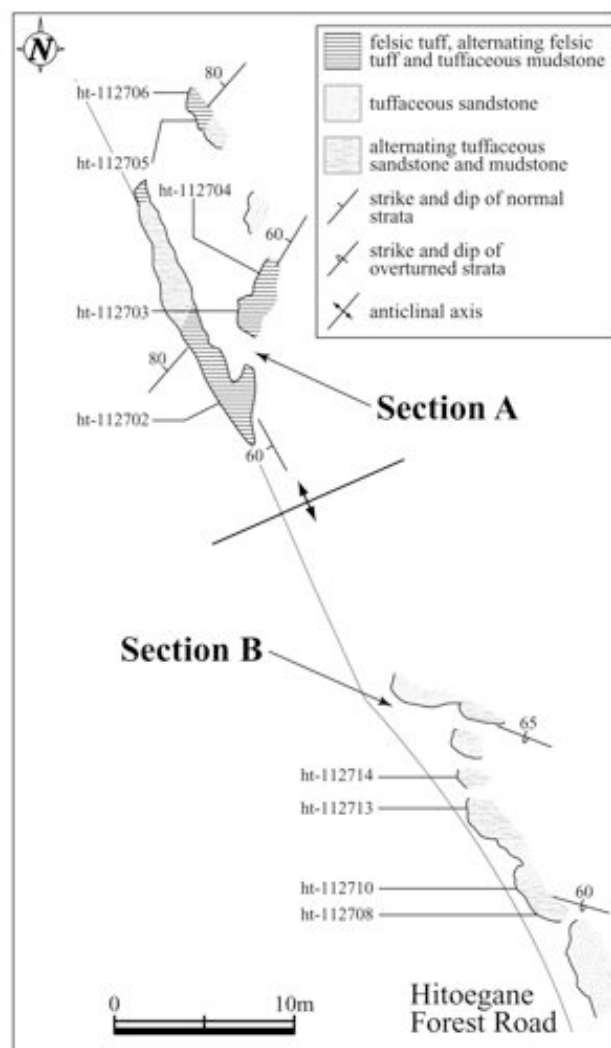
Since little independent age control existed for radiolarian horizons in the 1980s, stratigraphic correlations of these assemblages were discussed on the basis of incomplete biostratigraphic information. Furutani (1990) observed that *Zadrappolus spinosus*

closely resembles a spiny radiolarian species that ranges from upper Wenlockian to lower Ludlovian (Goodbody 1982, pl. 1, fig. 7). He thus assigned the *Spongocoelia parvus-Spongocoelia kamitakarensis* Assemblage to the Ludlovian. After Furutani's (1990) study, Noble (1994) proposed the *Praespongocoelia* Taxon Range Zone for a Wenlockian-Ludlovian layer, and correlated the *S. parvus-S. kamitakarensis* Assemblage with this zonal fauna. More recently, Noble and Aitchison (2000) suggested that the range of *Praespongocoelia* is restricted to lower to middle Ludlovian. As to correlation of the *Stylosphaera* (?) sp. A-*Stylosphaera* (?) sp. B Assemblage, Furutani (1990) treated it as a Lower or Middle Devonian assemblage, because he attached importance to the morphological similarities of *Stylosphaera* (?) species with Devonian *Trilonche* species. However, Noble (1994) clearly showed that the *Stylosphaera* (?) sp. A-*Stylosphaera* (?) sp. B Assemblage correlates with her Ludlovian-Pridolian *Stylosphaera* (?) *magnaspina* Taxon Range Zone fauna. To sum up, the assemblages recognized by Furutani (1990) from the Hitoegane area are restricted to a Ludlovian or slightly higher stratigraphic levels. This assignment is consistent with the constraint from trilobites in the upper part of the Hitoegane Formation (Kobayashi and Hamada 1987; Tazawa and Kaneko 1991).

NEW RADIOLARIAN HORIZONS AND THE LITHOLOGY OF RADIOLARIAN-BEARING ROCKS

Uppermost Silurian to Lower Devonian radiolarians were newly recovered in this study from tuffaceous rocks exposed along the Hitoegane forest road and in the left bank of the Gamatagawa River (sections A and B and sample ht-081504 locality, text-figures 2 and 4). Furutani (1990) did not study the localities from which my radiolarian samples were collected. The rock sequence about 14 meters thick in Section A is composed of tuffaceous sandstone, tuffaceous mudstone and felsic tuff. They strike N30°W to N40°E and dip 60°N to 80°N and form the NW limb of a gentle SW plunging anticline. The tuffaceous sandstone is fine- to medium-grained wacke, gray to bluish gray in color, and weakly stratified. The tuffaceous mudstone is bluish gray in color, and is frequently thinly interbedded with tuffaceous sandstone. The tuffaceous mudstone consists of silt-sized quartz grains and numerous radiolarian spheres in a muddy matrix together with very angular sand-sized quartz grains. Graded bedding is present within alternating tuffaceous sandstone and mudstone and shows that this section consists of a northwest- or west-younging sequence. Felsic tuff is pale blue to pale green in color and lithologically very similar to chert in very fine-grained portions. Six fine-grained tuffaceous rock samples (ht-112702 to ht-112706) were collected from Section A, with the sampling horizons shown in text-figures 4 and 5. Radiolarians were recovered from all samples by using a standard hydrofluoric acid etching technique (Pessagno and Newport 1972).

From tuffaceous strata (Section B, text-figures 2 and 4) about 14 meters thick and exposed along the forest road, 10 samples were collected from four of which moderately well-preserved radiolarians were recovered (ht-112708, 10, 13, 14). The rocks of Section B strike N75°W to N80°W and dip 65°N to 75°N. Southward-fining gradations within tuffaceous sandstone indicate that this limb of the anticline is overturned. These bluish gray tuffaceous sandstones and mudstones occupy a slightly higher stratigraphic position than the rocks of Section A (text-figures 4 and 5).



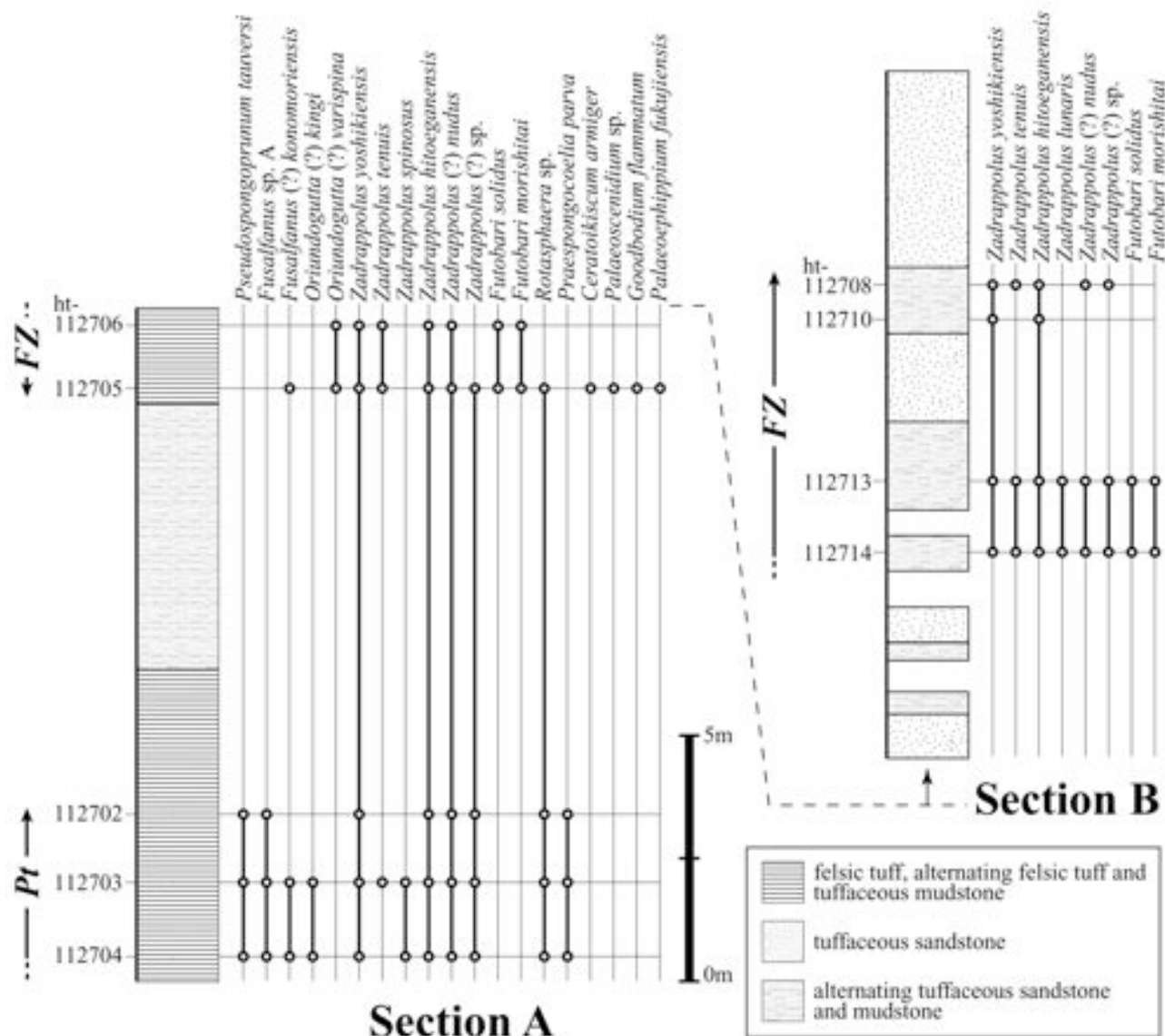
TEXT-FIGURE 4

Route map showing study sections along the Hitoegane Forest Road. See text-figure 2 for the location of these sections.

Tuffaceous radiolarian-bearing rocks which are lithologically similar to those in sections A and B crop out in the left bank of the Gamatagawa River. The strata from which sample ht-081504 was collected (text-figure 2) are estimated to be over 200 meters stratigraphically higher than Section A and correspond to the uppermost part of the Hitoegane Formation. According to Igo (1990), plant fossils mentioned above were likely collected in the vicinity of these radiolarian-bearing rocks.

RADIOLARIAN ASSEMBLAGES AND AGE ASSIGNMENTS

Abundant radiolarians were recovered from nine samples in sections A and B and sample ht-081504 in the upper part of the Hitoegane Formation. The species clearly make up two distinct assemblages, the *Pseudospongoprimum tauversi* Assemblage and the *Futobari solidus-Zadrappolus tenuis* Assemblage, which are named for their characteristic or most-abundant species.



TEXT-FIGURE 5

Columns for the study sections, showing radiolarian-bearing horizons and occurrences of radiolarian species. Abbreviations *Pt* stands for the *Pseudospongoprimum tauversi* Assemblage and *FZ* for the *Futobari solidus*-*Zadrappolus tenuis* Assemblage.

Pseudospongoprimum tauversi Assemblage

This assemblage occurs in the lower three samples of Section A (ht-112704, 03, 02; text-figure 5) and is characterized by *Pseudospongoprimum tauversi* Noble and the following diverse inanioguttid species: *Fusalfanus* sp. A, *Fusalfanus* (?) *konomoriensis* Aitchison, Hada, Ireland and Yoshikura, *Oriundogutta* (?) *kingi* Noble, *Zadrappolus yoshikiensis* Furutani, *Zadrappolus tenuis* Furutani, *Zadrappolus spinosus*, *Zadrappolus hitoeganensis*, *Zadrappolus* (?) *nudus* Kurihara n. sp., and *Zadrappolus* (?) sp. *Praespongocoelia parva* (Furutani) and *Rotasphaera* sp. also occur in the samples but are rare.

The nominative taxon *Pseudospongoprimum tauversi* was first described from the Caballos Novaculite, west Texas, as a representative species of the *Devoniglanus unicus*-*Pseudospongo-*

primum (?) *taueri* Interval Zone (Noble 1994). This zonal fauna consists of *Oriundogutta* and *Zadrappolus* species together with the two nominative species, and the last occurrence of *D. unicus* is in the middle of this zone. Since the *Pseudospongoprimum tauversi* Assemblage of the present study does not contain *D. unicus*, it can be correlated with the fauna in the upper half of the *D. unicus*-*P. (?) tauveri* Interval Zone. According to Noble (1994), the top of this zone contains a Ludlovian-Pridolian conodont fauna consisting of *Ozarkodina remscheidensis eosteinhornensis* (Walliser) ?, *Belodella* sp. and *Dapsilodus obliquicostatus* Bransen and Mehl. In addition, conodonts interpreted as Pridolian occur several meters above the top of this zone. Noble and Aitchison (2000) noted that the Postrotasphaerid Zone, which corresponds to the *D. unicus*-*P. (?) tauveri* Interval Zone, occurs no lower than lower

system	series/stage	Noble (1994)	Noble and Aitchison (2000)	This study
Devonian	(↑ 397.5)			(assemblages) <i>C. admissarius</i>
	Emsian			
	407.0 —		Entactiniid Superzone	<i>H. laticlavium</i>
	Pragian			<i>Tlecerina-Glanta</i>
	411.2 —			?
	Lochkovian			<i>Futobari solidus</i> - <i>Zadrappolus tenuis</i>
	416.0 —			
Silurian	Pridolian	<i>D. unicus</i> - <i>P. (?) tauversi</i>	Postrotasphaerid Zone	<i>H. speciosus</i> <i>Devoniglansus</i> - <i>Pseudospongoprimum</i>
	418.7 —	Rotasphaeracea- <i>D. unicus</i>		<i>Pseudospongoprimum</i> <i>tauversi</i>
	Ludlovian	<i>S. (?) magnaspina</i>	Long-spined inaniguttid Zone 3	<i>S. (?) magnaspina</i>
		<i>Praespongocoelia</i> - <i>S. (?) magnaspina</i>		<i>Praespongocoelia</i>
		<i>Praespongocoelia</i>		<i>P. asymmetrica</i>
		<i>P. (?) asymmetrica</i>		<i>I. tarangulica</i>
	422.9 —			
	Wenlockian			
	(↑ 428.2)			

TEXT-FIGURE 6

Correlation of radiolarian assemblages in the Hitoegane area with radiolarian zones of the Marathon uplift, west Texas (Noble 1994), and radiolarian zones and assemblages of Noble and Aitchison (2000). Numerical ages (Ma) are from Gradstein et al. (2004).

Ludlovian and no higher than upper Pridolian. Although strata containing the *P. tauversi* Assemblage lack independent age control, this assemblage is assignable to the Ludlovian to Pridolian, most probably lower to middle Pridolian, based on its correlation with the Upper Silurian radiolarian faunas discussed by Noble (1994) and Noble and Aitchison (2000) (text-figure 6).

Futobari solidus-*Zadrappolus tenuis* Assemblage

This assemblage is characterized by the abundance of *Futobari solidus* Furutani and *Zadrappolus tenuis*. Other inaniguttid species in this assemblage are *Fusalfanus (?) konomoriensis*, *Oriundogutta (?) varispina* Noble, *Zadrappolus yoshikiensis*, *Zadrappolus hitoeganensis*, *Zadrappolus lunaris* Noble, *Zadrappolus (?) nudus*, *Zadrappolus (?) sp.*, and *Futobari morishitai*. Rare *Rotasphaera* sp., *Goodbodium flammatum* (Goodbody), *Palaeohippium fukujiensis* Furutani, *Palaeoscenedium* sp., and *Ceratoikiscum armiger* Furutani also occur in the assemblage. It first occurs eight meters stratigraphically above strata containing the *Pseudospongoprimum tauversi* Assemblage (ht-112705 in Section A), and also in horizons that are stratigraphically higher than ht-112705 (ht-112706 of Section A, ht-112714, 13, 10, 08 of Section B). Sample ht-081504 from the uppermost part of the Hitoegane Formation also yields this assemblage.

Futobari solidus and closely related species have been reported from only a few localities in Japan. *F. solidus* was first described from Fukui in the Hida-gaien terrane by Furutani (1990), but

rocks at that locality lack age-diagnostic fossils. Aitchison et al. (1996) reported *F. solidus* and *Futobari morishitai* from two localities in the Kurosegawa terrane, Konomori and Jingamori. From the former locality, they analyzed SHRIMP dating using zircons from tuffaceous rocks and provided a U/Pb age of 408.9 ± 7.6 Ma, which was thought to be uppermost Silurian based on the geological time scale existed at that time (Odin 1994). In contrast, Umeda (1998) proposed the *Futobari solidus* Zone for the strata at Konomori and correlated this zone with the Pragian. However, he did not present reliable evidence for this age determination. The biostratigraphic results from Section A in the present study clearly show that the lower limit of the *Futobari solidus*-*Zadrappolus tenuis* Assemblage is no lower than upper Pridolian, considering its stratigraphic relationship to the underlying *Pseudospongoprimum tauversi* Assemblage. This assemblage was also recovered from more than 200 meters stratigraphically higher strata than Section A (sample ht-081504), which are close to the locality of probably Lower Devonian plants (Igo 1990). Concerning to the above-mentioned U/Pb age (408.9 ± 7.6 Ma) dated from Konomori (Aitchison et al. 1996), it is equivalent to the Pragian with error bars extending from uppermost Pridolian into the Emsian, based on the revaluation using the latest geologic time scale by Gradstein et al. (2004). In addition, recent work by this author and others on correlation of the *Tlecerina-Glanta* Assemblage described by Wakamatsu et al. (1990), which is recognized from stratigraphically higher deposits than *Futobari*-dominated

faunas, shows that this assemblage occurs in Lochkovian (or Pragian)-Emsian strata of the South Kitakami terrane (Kurihara et al. 2005). These also indicates an Emsian upper limit for the *F. solidus*-*Z. tenuis* Assemblage. Taken together, these data imply that the *F. solidus*-*Z. tenuis* Assemblage ranges from uppermost Silurian to Lower Devonian.

DISCUSSION

There is no doubt that Lower Devonian radiolarian zonations still need refinement through additional biostratigraphic and faunal studies, compared to Upper Silurian zones (Noble 1994) that have credible age control. That being said, as Aitchison et al. (1999) have stated, our immediate task is establishing a link between Upper Silurian zones (Noble 1994; Noble and Aitchison 2000) and well-dated Upper Devonian zones (Holdsworth and Jones 1980; Cheng 1986; Schwartzapfel and Holdsworth 1996). Recent work on Middle Devonian radiolarians has progressed remarkably toward meeting this goal, in Australia (Stratford and Aitchison 1997; Aitchison and Stratford 1997; Aitchison et al. 1999), the Czech Republic (Braun and Budil 1999), China (Luo et al. 2002; Wang et al. 2003) and Russia (Lipnitskaya 2003). I would like to emphasize that data in the present study serve to link the Silurian and Upper Devonian zones from the perspective of Silurian-Lower Devonian zonation. The *Futobari solidus*-*Zadrappolus tenuis* Assemblage of the present study is regarded as being younger than Noble's (1994) Pridolian fauna. Thus, it is clear that the *F. solidus*-*Z. tenuis* Assemblage is the earliest radiolarian fauna to flourish at the beginning of the Devonian. Faunas similar to the *F. solidus*-*Z. tenuis* Assemblage have already been reported as the *Zadrappolus yoshikiensis* Assemblage by Furutani (1990) and also by Aitchison et al. (1996) and Umeda (1998), but the present study is the first to clarify the stratigraphic relationship of this assemblage to Silurian assemblages and maximum age range (text-figure 6). This conclusion differs from Noble (1994), who correlated the *Z. yoshikiensis* Assemblage with her Ludlovian fauna. Taking into consideration that she did not report both *Futobari solidus* or *Futobari morishitai* in any of her Upper Silurian faunas, it is reasonable to think that the *F. solidus*-*Z. tenuis* Assemblage does not overlap with any of Noble's (1994) Silurian zonal faunas.

Noble and Aitchison (2000) set up the Postrotasphaerid Zone and the Entactiniid Superzone as uppermost Silurian-Devonian radiolarian zones. The lower limit of the Entactiniid Superzone is defined by the first abundant occurrence of the typical entactiniid genus *Stigmosphaerostylus* with tribladed spines, and Noble and Aitchison (2000) tentatively placed it at the base of the Devonian. The Entactiniid Superzone is literally characterized by the common occurrence of entactiniids such as *Stigmosphaerostylus* and *Trilonche*. The present study implies that the interval from lowermost Devonian to probable Pragian occupies the final acme of the inaniguttid group. According to Umeda (1998) and Kurihara and Sashida (2000a), a subsequent fauna showing the decline of the inaniguttid-dominated fauna is a palaeoscanidiid-dominated fauna that contains an abundance of entactiniids. Thus, the base of the Entactiniid Superzone should be placed in the Pragian or slightly higher. Current research has not demonstrated what the major contributor was to the faunal change from an inaniguttid-dominated fauna to a palaeoscanidiid-dominated fauna. Nevertheless this faunal change can be viewed as a significant turning point from a Silurian-type fauna to a Devonian-type fauna, and to which more attention should be paid.

In this study, I have emphasized the theme of two uppermost Silurian-Lower Devonian assemblages, though, other distinctive assemblages ranging from Lower Silurian to Lower Devonian have been reported from the Hida-gaien terrane (Furutani 1990; Kurihara and Sashida 2000a, b). Until now, Japanese Middle Paleozoic material, including the Hida-gaien faunas, have made little contribution toward development of a zonation, due to the discontinuity of measured sections and scarce co-occurring index fossils. The present results, however, show that careful work focused on the biostratigraphic context of these assemblages, and on recognizing significant biohorizons, can significantly improve the existing zonation. In a parallel study, I am conducting research on organic-walled microfossils that co-occur with radiolarians. I am hopeful about the integration of radiolarian and organic-walled microfossil biostratigraphy for improving the calibration of Middle Paleozoic time.

SYSTEMATIC PALEONTOLOGY

All figured specimens are deposited in the Institute of Geoscience, University of Tsukuba, and are assigned IGUT numbers.

Suborder SPUMELLARIA Ehrenberg 1875

Family SPONGURIDAE Haeckel 1887; emend. Pessagno 1973

Genus *Pseudospongoprimum* Wakamatsu, Sugiyama and Furutani 1990

Type species: Pseudospongoprimum tazukawaensis Wakamatsu, Sugiyama and Furutani 1990

Pseudospongoprimum tauversi Noble 1994

Plate 1, figures 1-4

Pseudospongoprimum (?) *tauversi* NOBLE 1994, p. 28, pl. 7, figs. 13-15.
- SUZUKI, TAKAHASHI and KAWAMURA 1996, fig. 4-5.

Description: The external shell shape is subspherical, ovate, and edellipsoidal, and the shell is composed of dense spongiöse meshwork. Material recovered in this study is poorly preserved, and internal details of the spongiöse shell are unclear. Spines are bi-polar and strongly tapered distally. The proximal portions of the spines are shallowly grooved.

Remarks: By the cautious treatment of Noble (1994), the present species, with its concentrically layered, spongiöse shell was tentatively placed in *Pseudospongoprimum*, because Wakamatsu et al. (1990) did not note the existence of concentric layering in this genus, except for a faintly layered structure. As Aitchison et al. (1996) mentioned, however, the presence of these layers strongly depends on the preservation state of the prepared specimens. The external subspherical to ellipsoidal spongiöse shell with bi-polar spines meets the requirements for this genus, so it is placed within *Pseudospongoprimum*. Aitchison et al. (1996) treated *Pseudospongoprimum tauversi* as a junior synonym of *Pseudospongoprimum sagittatum* Wakamatsu, Sugiyama and Furutani. However, the present species differs from *P. sagittatum* by having a more oval-shaped shell and robust spines on its proximal parts. *Pseudospongoprimum tazukawaensis* Wakamatsu, Sugiyama and Furutani differs from this species in having a looser spongiöse meshwork and thinner spines.

Range and occurrence: Upper Silurian. Marathon uplift in west Texas; Kamaishi area of the South Kitakami terrane in northeast Japan; Hitoegane area of the Hida-gaien terrane in central Japan.

Family INANIGUTTIDAE Nazarov and Ormiston 1984;
emend. Noble 1994

Genus *Fusalfanus* Furutani 1990

Type species: *Fusalfanus osobudaniensis* Furutani 1990

Fusalfanus sp. A

Plate 1, figures 5-9

Description: The skeleton of this species is composed of a medullary shell (shells?) and one thick cortical shell with a delicate shell. The nature of the medullary shell remains uncertain in the material at hand (pl. 1, fig. 9). The cortical shell is finely spongy, and spherical to slightly elliptical in shape. The trace of the delicate cortical shell is exhibited as small spinules arising from external spines or trident-shaped external spines. A pylome, one of the diagnostic characters of this genus, is observable on one specimen (white arrow in pl. 1, fig. 6), but it cannot be observed on other, relatively poorly preserved specimens. External spines, which generally have small spinules, are rod-shaped or conical and highly taper toward the distal ends, with weakly developed grooves on their proximal parts.

Remarks: Although this species does not have a large, pronounced pylome, as does *Fusalfanus osobudaniensis* Furutani, it is placed within *Fusalfanus*, because the external appearance of this species resembles that of *Fusalfanus* rather than *Inanihella*. This species is similar in external shape to *F. osobudaniensis*, but differs from the latter in possessing thinner spines and a smaller shell diameter.

Range and occurrence: Upper Silurian. Hitoegane area in the Hida-gaien terrane.

Fusalfanus (?) *konomoriensis* Aitchison, Hada, Ireland and Yoshikura 1996

Plate 1, figures 10-14

Indeterminable Spumellaria with a large pylome FURUTANI 1990, pl. 13, fig. 9. Undescribed new species AITCHISON, HADA and YOSHIKURA 1991, fig. 3-G.

Fusalfanus (?) *konomoriensis* AITCHISON, HADA, IRELAND and YOSHIKURA 1996, p. 66, pl. 1, figs. 15, 17, 19, 20. – UMEDA 1998, fig. 10-2.

Fusalfanus konomoriensis Aitchison, Hada, Ireland and Yoshikura 1996 – UMEDA 1997, p. 422, pl. 4, fig. 18, 19.

Description: The cortical shell is very large, spherical to subspherical in shape, and finely porous. Ten to fifteen external spines arise from a hemisphere of the cortical shell. They are short, conical, and grooved on the proximal parts. A large pylome is present on the cortical shell and is framed by four to six short spines. These surrounding spines are shorter and thinner than other external spines. Due to fine siliceous fillings inside the cortical shell, there are no specimens with observable internal structures.

Remarks: This species is characterized by a large cortical shell diameter (usually over 310 µm) and a distinct pylome framed by spines. Other species of *Fusalfanus* have double medullary shells, although the nature of internal structures is unclear in material from this study. In addition, a delicate outer cortical shell, or its trace, which is a diagnostic feature of this genus, has not been observed, so the taxonomic placement of this species is still tentative. Although both the holotype and paratype figured by Aitchison et al. (1996) do not have a large cortical shell and short spines framing the pylome, some specimens collected

from the type locality have similar skeletal features to the specimens from this study (J. C. Aitchison pers. comm.).

Range and occurrence: Upper Silurian to Lower Devonian. Konomori and Yokokurayama areas in the Kurosegawa terrane; Fukuji and Hitoegane areas in the Hida-gaien terrane.

Genus *Oriundogutta* Nazarov 1988

Type species: *Astroentactinia ramificans* Nazarov 1975

Oriundogutta (?) *kingi* Noble 1994

Plate 1, figures 15-18

Inanihella macroacantha (Rüst 1892) - NAZAROV 1988, p. 209, pl. XII, fig. 1.

Inanihella macroacantha ? (Rüst 1892) - NAZAROV and ORMISTON 1993, p. 37, pl. 2, figs. 6-8.

Oriundogutta (?) *kingi* NOBLE 1994, p. 31, pl. 6, figs. 1, 4. - KURIHARA and SASHIDA 1998, pl. 1, fig. 7. - KURIHARA and SASHIDA 2000a, p. 58, pl. 1, figs. 5, 6. – KURIHARA 2003, fig. 8-2.

Oriundogutta ? sp. cf. *O. kingi* Noble 1994 - AITCHISON, HADA, IRELAND and YOSHIKURA 1996, p. 67, pl. 2, fig. 15.

Remarks: This species is characterized by one thick cortical shell having more than ten thick external spines. External spines may originally have been long, but most are broken in the Hitoegane specimens. The cortical shell is very large, and its average diameter reaches 250 to 300 µm. This species is superficially similar to species of *Zadrappolus*, especially *Zadrappolus yoshikiensis*. However, the structure and number of the medullary shells is still unclear in *O. (?) kingi*, so its taxonomic position is tentative. This species differs from *Oriundogutta* (?) *varispina* Noble in possessing a larger number of robust spines and slightly smaller shell diameter.

Range and occurrence: Upper Silurian. Southern Urals; Marathon uplift in west Texas; Ise (Kuzuryu Lake) and Hitoegane areas in the Hida-gaien terrane; Yoshinozawa-guchi area in the Kurosegawa terrane.

Oriundogutta (?) *varispina* Noble 1994

Plate 1, figures 19, 20

Oriundogutta (?) *varispina* NOBLE 1994, p. 31, pl. 6, figs. 2, 3, pl. 9, fig. 4.

Remarks: This species is characterized by a thick, latticed large cortical shell with seven or more robust external spines per hemisphere. The spine of this species, which is weakly grooved at its proximal portion and slightly to highly tapered distally, bears a strong morphological similarity to that of *Oriundogutta* (?) *kingi* Noble. This species, however, differs from *O. (?) kingi* in having thinner and less numerous external spines.

Range and occurrence: Uppermost Silurian. Marathon uplift in west Texas; Hitoegane area in the Hida-gaien terrane.

Genus *Zadrappolus* Furutani 1990

Type species: *Zadrappolus yoshikiensis* Furutani 1990

Zadrappolus yoshikiensis Furutani 1990

Plate 1, figures 21-24

Zadrappolus yoshikiensis FURUTANI 1990, p. 35-36, pl. 2, figs. 4-6; pl. 3, figs. 1-2. - NOBLE 1994, p. 32, pl. 6, figs. 14-16. - UMEDA 1997, p. 421, pl. 4, fig. 10. - KURIHARA and SASHIDA 1998, pl. 1, figs. 1, 2. - KURIHARA and SASHIDA 2000a, p. 58, pl. 1, figs. 1, 2.

Remarks: This species is one of the most common throughout the *Pseudospongoprimum tauversi* and *Futobari solidus*-

Zadrappolus tenuis assemblages in the study area. Although the presence of two medullary shells, which is a diagnostic character of this species described by Furutani (1990), cannot be observed because internal detail is not visible on many specimens, the external appearance of the irregularly porous, spherical shell with more than twenty short and conical, proximally bladed spines places it in *Zadrappolus yoshikiensis*. This species is distinguished from *Zadrappolus tenuis* by possessing short conical or strongly tapered spines, in contrast to which the latter has long cylindrical spines. *Zadrappolus spinosus* differs from this species by having numerous thin spines and a larger diameter to its spherical shell. A form having weakly developed conical spines in this species is somewhat similar to *Zadrappolus hitoeganensis*, but the latter is characterized by thin cylindrical spines.

Range and occurrence: Upper Silurian to Lower Devonian. Fukuji, Ise, and Hitoegane areas in the Hida-gaien terrane; Marathon uplift in west Texas; Konomori area of the Kurosegawa terrane in southwest Japan.

***Zadrappolus tenuis* Furutani 1990**
Plate 1, figures 25-29

Zadrappolus tenuis FURUTANI 1990, p. 36-37, pl. 3, figs. 3-6. – NOBLE 1994, p. 32, pl. 6, figs. 10, 12, 13. – AITCHISON, HADA, IRELAND and YOSHIKURA 1996, p. 67, pl. 1, figs. 1, 6; pl. 2, fig. 6; pl. 3, figs. 1, 2, 15. – KURIHARA and SASHIDA 1998, pl. 1, fig. 3. – UMEDA 1998, fig. 9-7. – KURIHARA and SASHIDA 2000a, p. 58, pl. 1, fig. 3.
Spumellaria gen. indet. sp. I WAKAMATSU, SUGIYAMA and FURUTANI 1990, p. 177, pl. 3, figs. 9-11.
Zadrappolus sp. aff. *Z. tenuis* Furutani 1990 - NOBLE 1994, p. 32, pl. 6, fig. 11.
Inanihella aff. *macroacantha* (Rüst 1892) - LI 1994, p. 261, pl. 2, figs. 13, 16.
Zadrappolus (?) *tenuis* Furutani 1990 - UMEDA 1997, p. 421, pl. 2, figs. 8-15.
Zadrappolus (?) sp. aff. *Z. tenuis* Furutani 1990 - UMEDA 1997, p. 421, pl. 4, figs. 11-12.

Remarks: This species is common in both assemblages recognized in this study, being especially abundant in the younger *Futobari solidus-Zadrappolus tenuis* Assemblage. The *Zadrappolus* species with long, cylindrical spines are placed within *Zadrappolus tenuis* herein, although the spine number and length show greater variability. The Hitoegane specimens have six to twelve spines per hemisphere, with some of the best-preserved specimens having more than twenty spines (figured by Furutani 1990, pl. 3, figs. 3, 4), and the spines are commonly bent (figured by Aitchison et al. 1996, pl. 3, fig. 2). This species differs from *Zadrappolus spinosus* and *Zadrappolus hitoeganensis* in possessing thicker and less numerous spines.

Range and occurrence: Upper Silurian to Lower Devonian. Fukuji, Ise, and Hitoegane areas in the Hida-gaien terrane; Konomori, Gioniyama, Kasamigawa, and Jingamori areas in the Kurosegawa terrane; Marathon uplift in west Texas; Mayila area in west Junggar, China.

***Zadrappolus spinosus* Furutani 1990**
Plate 2, figures 1-4

Zadrappolus spinosus FURUTANI 1990, p. 37, pl. 4, figs. 1-4. – NOBLE 1994, p. 32, pl. 6, fig. 6; pl. 9, figs. 9, 11.
Zadrappolus aff. *spinosus* Furutani 1990 - KURIHARA and SASHIDA 1998, pl. 1, fig. 4. – KURIHARA and SASHIDA 2000a, p. 58, pl. 1, fig. 4.

Remarks: Shell consists basically of two medullary shells and a cortical shell. This species is characterized by more than 80 external spines on a hemisphere of a cortical shell. These spines are thin and conical to cylindrical in shape, and their length is variable, but they commonly are short and about 20µm in length. The cortical shell is large (over 300µm), latticed, and spherical to slightly elliptical in external shape. The external appearance is similar to that of *Zadrappolus hitoeganensis*, but is easily distinguished from the latter species by the larger diameter of its cortical shell and its greater number of external spines.

Range and occurrence: Upper Silurian. Fukuji, Ise, and Hitoegane areas in the Hida-gaien terrane; Marathon uplift in west Texas.

***Zadrappolus hitoeganensis* Furutani 1990**
Plate 2, figures 5-7

Zadrappolus ? *hitoeganensis* FURUTANI 1990, p. 37-38, pl. 4, figs. 5, 6; pl. 5, fig. 1.

Remarks: The basic skeleton of this species is composed of a spherical cortical shell with more than 20 short external spines per hemisphere. Furutani (1990) tentatively assigned this species to *Zadrappolus*, because the medullary shell structure is unclear. Based on observations of specimens collected from the type locality (Furutani, 1990, horizon H-7), however, this species has double medullary shells and no internal spicule. Therefore, it is formally assigned to *Zadrappolus* herein. Furutani (1990) mentioned that this species has a moderately large cortical shell (170 to 180 µm). However, measurements of 35 specimens show that the cortical shell diameter ranges from 140 to 180 µm, with an average of 157 µm, so this species does not have a particularly large cortical shell. This species is somewhat similar to *Zadrappolus spinosus*, except that it has a rather small shell diameter and a smaller number of external spines.

Range and occurrence: Upper Silurian to Lower Devonian. Fukuji and Hitoegane areas in the Hida-gaien terrane.

***Zadrappolus lunaris* Noble 1994**
Plate 2, figures 8-10

Spumellaria gen. indet. sp. D WAKAMATSU, SUGIYAMA and FURUTANI 1990, p. 175, pl. 8, fig. 4.
Zadrappolus lunaris NOBLE 1994, p. 32-33, pl. 6, figs. 7, 8; pl. 9, fig. 8.

Remarks: This species rarely occurs in strata containing the *Futobari solidus-Zadrappolus tenuis* Assemblage. According to Noble (1994), the cortical shell diameter of this species, measured on six specimens, ranges from 158 to 183µm, but my specimens have a slightly larger cortical shell that commonly reaches 250µm. This species differs from other species of *Zadrappolus* in the presence of short conical external spines that are few abundant.

Range and occurrence: Uppermost Silurian to Lower Devonian. Marathon uplift in west Texas; Hitoegane area in the Hida-gaien terrane.

***Zadrappolus* (?) *nudus* Kurihara n. sp.**
Plate 2, figures 11-14

Oriundogutta sp. AITCHISON, HADA, IRELAND and YOSHIKURA 1996, p. 66-67, pl. 2, fig. 14.

Diagnosis: Large, spherical cortical shell with inconspicuous thin external spines; spines are very short, conical, with approximately ten per hemisphere.

Description: The basic skeleton of this species consists of a medullary shell (shells?) and a cortical shell with very short external spines. The medullary shell structure is not observable in the Hitoegane specimens. One thick cortical shell is very large, spherical and finely porous. External spines arising from the cortical shell surface are very short, small, conical and have very weak grooves on their proximal parts. The number of spines is about ten per hemisphere, but on some specimens may be less than five.

Measurement: Based on 22 specimens (μm): Diameter of cortical shell 300 to 390 (holotype 360; average 340).

Remarks: Although the nature of the medullary shell is uncertain in Hitoegane material, I have confirmed the presence of the medullary shell in specimens collected from the Fukuji area, Hida-gaien terrane. The medullary shell of the Fukuji specimens is similar to that of *Oriundogutta* sp. described by Aitchison et al. (1996, pl. 2, fig. 14). However, the presence of an inner medullary shell still remains uncertain, so the placement of this species in *Zadrappolus* is tentative. This species is easily distinguished from other species of *Zadrappolus* by its very large cortical shell with less-developed conical spines.

Etymology: The species name is derived from Latin *nudus* -a -um, for naked.

Type material: Holotype, IGUT-TK3199 (pl. 2, fig. 12); paratypes, IGUT-TK3177 (pl. 2, fig. 11), IGUT-TK3676 (pl. 2, fig. 13), IGUT-TK3699 (pl. 2, fig. 14).

Type locality: Hitoegane (ht-112705). See locality descriptions, text-figures 2 and 4.

Range and occurrence: Upper Silurian to Lower Devonian. Yoshinozawa-guchi area in the Kurosegawa terrane; Hitoegane area in the Hida-gaien terrane.

***Zadrappolus* (?) sp.**

Plate 2, figures 15, 16

Inanihella ? sp. cf. *I. duroacus* NAZAROV and ORMISTON 1993. – AITCHISON, HADA, IRELAND and YOSHIKURA 1996, p. 66, pl. 3, figs. 10, 13.

Remarks: This species is characterized externally by a moderately large cortical shell and approximately 30 robust, rod-like tapered external spines. *Inanihella* ? sp. cf. *I. duroacus* Nazarov and Ormiston, described by Aitchison et al. (1996) from the Jingamori and Konomori areas of the Kurosegawa terrane, is conspecific with this species. The present taxon, however, does not have a delicate outer cortical shell or its remnant, so I tentatively place it within *Zadrappolus*, based on its external appearance.

Range and occurrence: Upper Silurian to Lower Devonian. Hitoegane area in the Hida-gaien terrane; Jingamori and Konomori areas in the Kurosegawa terrane.

Genus ***Futobari*** Furutani 1990

Type species: *Futobari solidus* Furutani 1990

Futobari solidus Furutani 1990

Plate 2, figures 17-21

Futobari solidus FURUTANI 1990, p. 34, pl. 1, figs. 1-4. – AITCHISON, HADA, IRELAND and YOSHIKURA 1996, p. 65, pl. 6, figs. 3, 8. – UMEDA 1997, p. 422, pl. 4, figs. 14-17. – UMEDA 1998, fig. 9-12.

Spumellaria gen. indet. sp. A WAKAMATSU, SUGIYAMA and FURUTANI 1990, p. 174, pl. 8, figs. 1a, b.

Spumellaria gen. indet. sp. E WAKAMATSU, SUGIYAMA and FURUTANI 1990, p. 175, pl. 8, fig. 5.

Remarks: This species is characterized by the presence of six long, robust external spines. These spines have shallow grooves on their basal portion and gently taper distally. Well preserved spines attain a length of 300 μm . This species is distinguished from *Futobari morishitai* by its smaller number of external spines. Both *Futobari* (?) *tosaensis* Aitchison, Hada, Ireland and Yoshikura and *Futobari* (?) *jingamoriensis* Aitchison, Hada, Ireland and Yoshikura, described from the Jingamori area in the Kurosegawa terrane, differ from this species in having greater numbers of external spines that distinctively taper distally and possess broader proximal parts.

Range and occurrence: Uppermost Silurian to Lower Devonian. Fukuji and Hitoegane areas in the Hida-gaien terrane; Konomori and Jingamori areas in the Kurosegawa terrane.

Futobari morishitai Furutani 1990

Plate 2, figures 22, 23

Futobari morishitai FURUTANI 1990, p. 35, pl. 1, fig. 5, pl. 2, figs. 1-3. – UMEDA 1997, p. 421-422, pl. 2, fig. 16; pl. 4, fig. 13. – UMEDA 1998, fig. 9-6.

Futobari sp. cf. *F. morishitai* Furutani 1990 – AITCHISON, HADA, IRELAND and YOSHIKURA 1996, p. 65, pl. 1, fig. 18; pl. 2, fig. 13; pl. 3, fig. 11.

Remarks: This species characteristically has four to six external spines on a hemisphere. The external spines are slightly thinner than those of *Futobari solidus*. Furutani (1990) noted that this species has a smaller cortical shell than *F. solidus*. However, both *F. solidus* and *F. morishitai* from the Hitoegane area have approximately the same cortical shell diameter. This species differs from *Futobari* (?) *jingamoriensis* and *Futobari* (?) *tosaensis* in having less tapered external spines with thin, weakly grooved proximal portions.

Range and occurrence: Uppermost Silurian to Lower Devonian. Fukuji and Hitoegane areas in the Hida-gaien terrane; Konomori, Yoshinozawa-guchi, and Jingamori areas in the Kurosegawa terrane.

Family ROTASPHAERIDAE Noble 1994; emend. MacDonald 1998; Noble and Maletz 2000; Won, Blodgett and Nestor 2002
Genus *Rotasphaera* Noble 1994; emend. MacDonald 1998 Type species: *Rotasphaera marathonensis* Noble 1994

Rotasphaera sp.

Plate 2, figure 25

Secuicollacta sp. indet. FURUTANI 1990, pl. 13, fig. 2.

Remarks: Three poorly preserved specimens were obtained from strata containing the *Pseudospongoprimum tauversi* Assemblage. Definitive primary spine units (Noble 1994) can be observed in the figured specimen. A specimen conspecific with this species has been reported from the Ichinotani Section in the Fukuji area, Hida-gaien terrane by Furutani (1990, pl. 13, fig. 2), along with co-occurring *Futobari solidus* and *Futobari morishitai*. Noble (1994) suggested that the last appearance of rotasphaerid species is present within her Ludlovian *Stylosphaera* (?) *magnaspina* Taxon Range Zone (Noble and Aitchison 2000). Although the biostratigraphic significance of rotasphaerid species, especially their acme, is not disputed, the

Hida-gaien material shows that some rotaspherid species survived into the Lower Devonian.

Range and occurrence: Upper Silurian to Lower Devonian. Fukuji and Hitoegane areas in the Hida-gaien terrane.

Family INCERTAE SEDIS

Genus *Praespongocoelia* Noble 1994

Type species: *Spongocoelia parvus* Furutani 1990

Praespongocoelia parva (Furutani 1990); emend. Noble 1994
Plate 2, figure 24

Spongocoelia parvus FURUTANI 1990, p. 47-48, pl. 9, figs. 6, 7; pl. 10, fig. 1.

Spongocoelia kamitakarensis FURUTANI 1990, p. 48-49, pl. 10, figs. 2-4.

Praespongocoelia parva NOBLE 1994, p. 38, pl. 7, figs. 1-4.

Remarks: This species is rare in strata containing the *Pseudospongoprimum tauversi* Assemblage. Its skeleton is characterized by a moderately large spherical to subspherical spongioid shell (more than 150 µm) with bipolar spines. The internal structure of the spongioid shell is unclear. The polar spines are conical to rod-like and strongly taper toward each distal end. Furutani (1990) proposed *Spongocoelia kamitakarensis* Furutani, which characteristically has a slightly larger shell (140 to 170 µm). However, both the present species and *S. kamitakarensis* have the same skeletal morphology, and the difference between these species can be attributed to intraspecific variation. Therefore, *S. kamitakarensis* is placed in synonymy with *P. parva*. This species is easily distinguished from *Praespongocoelia fusiforma* Noble by its spherical shell and thinner bipolar spines. Noble and Aitchison (2000) figured the range of this genus as being restricted to the lower Ludlovian, but it appears that a few representative of *P. parva* survived into the upper Ludlovian to lower Pridolian.

Range and occurrence: Upper Silurian. Fukuji and Hitoegane areas in the Hida-gaien terrane; Marathon uplift in west Texas.

Suborder ALBAILLELLARIA Deflandre 1953; emend. Holdsworth 1969 Family CERATOIKISCIDAE Holdsworth 1969
Genus *Ceratoikiscum* Deflandre 1953

Type species: *Ceratoikiscum avimexpectans* Deflandre 1953

Ceratoikiscum armiger Furutani 1990

Plate 2, figure 29

Ceratoikiscum armiger FURUTANI 1990, p. 51-52, pl. 12, figs. 2-4. - AMON, BRAUN and IVANOV 1995, p. 4, pl. 1, figs. 1, 2. - UMEDA 1997, p. 419, pl. 1, fig. 19; pl. 3, figs. 15-17. - UMEDA 1998, fig. 9-9. - KURIHARA and SASHIDA 1998, pl. 1, figs. 11, 12. - KURIHARA and SASHIDA 2000a, p. 63, pl. 1, figs. 12, 13.

Ceratoikiscum sp. FURUTANI 1996, fig. 7-5.

Remarks: Eight poorly preserved specimens were obtained from strata containing the *Futobari solidus-Zadrappolus tenuis* Assemblage (ht- 112705 in Section A). This species bears a strong morphological similarity to *Ceratoikiscum lyratum* Ishiga. However, the former differs from the latter in possessing a weakly developed patagium and less-ornamented, thin caveal ribs.

Range and occurrence: Upper Silurian to Lower Devonian. Fukuji, Ise (Kuzuryu Lake), and Hitoegane areas in the Hida-gaien terrane; Konomori and Yokokurayama areas in the Kurosegawa terrane; Southern Urals.

Incertae sedis

Family PALAEOSCENIDIIDAE Riedel 1967; emend. Holdsworth 1977, Goodbody 1982, Furutani 1983, Goodbody 1986, MacDonald 2004

Genus *Palaeoscenidium* Deflandre 1953; emend. Goodbody 1986
Type species: *Palaeoscenidium cladophorum* Deflandre 1953

Palaeoscenidium sp.

Plate 2, figure 27

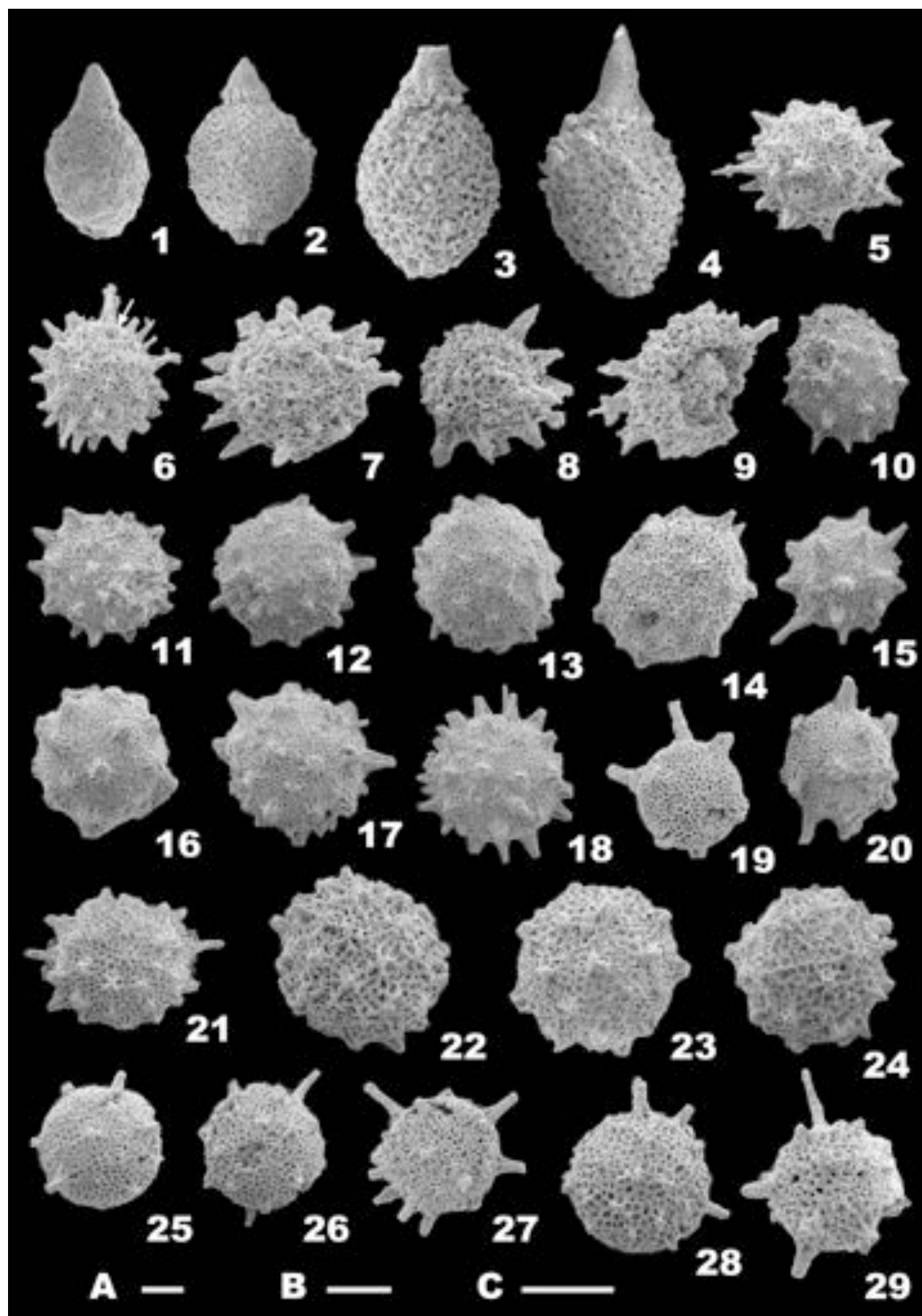
Palaeoscenidium sp. indet. FURUTANI 1990, p. 42-43, pl. 7, figs. 8-9.

PLATE 1

Scale bars, A to C, equal to 100µm: A applies to 10-13, 15-20, B to 1, 2, 5, 6, 14, 21, 25-27, C to 3, 4, 7-9, 22-24, 28, 29.

- 1-4 *Pseudospongoprimum tauversi* Noble. 1, sample ht-112702, IGUT-TK2462; 2, sample ht-1 12704, IGUT-TK3055; 3, sample ht-1 12702, IGUT-TK2623; 4, sample ht-1 12702, IGUT-TK2636
- 5-9 *Fusalfanus* sp. A. 5, sample ht-112704, IGUT-TK2942; 6, sample ht-112703, IGUT-TK2730; 7, sample ht-1 12702, IGUT-TK2535; 8, sample ht-1 12702, IGUT-TK2579; 9, sample ht-1 12702, IGUT-TK2506
- 10-14 *Fusalfanus* (?) *konomoriensis* Aitchison, Hada, Ireland and Yoshikura, 10, sample ht-1 12703, IGUT-TK281 8; 11, sample ht-1 12704, IGUT-TK2977; 12, sample ht- 112703, IGUT-TK2903; 13, sample ht-112703, IGUT-TK2906; 14, sample ht-1 12704, IGUT-TK3071

- 15-18 *Oriundogutta* (?) *kingi* Noble. 15, ht-sample 112704, IGUT-TK3 002; 16, sample ht-1 12703, IGUT-TK271 1; 17, sample ht-1 12703, IGUT-TK2789; 18, sample ht-1 12703, IGUT-TK2820
- 19,20 *Oriundogutta* (?) *varispina* Noble. 19, sample ht-1 12705, IGUT-TK3209; 20, sample ht-112705, IGUT-TK3223
- 21-24 *Zadrappolus yoshikiensis* Furutani. 21, sample ht-112704, IGUT-TK2974; 22, sample ht-112703, IGUT-TK2935; 23, sample ht-112713, IGUT-TK3564; 24, sample ht-112713, IGUT-TK3574
- 25-29 *Zadrappolus tenuis* Furutani, 25, sample ht-112706, IGUT-TK3391; 26, sample ht-1 12706, IGUT-TK3346; 27, sample ht- 112706, IGUT-TK345 1; 28, sample ht-1 12705, IGUT-TK3258; 29, sample ht-08 1504, IGUT-TK4840



Palaeoscenidium sp. WAKAMATSU, SUGIYAMA and FURUTANI 1990, pl. 3, fig. 8.

Remarks: The present taxon is common in sample ht-1 12705 from Section A, but all the specimens are poorly preserved. The basic skeleton is composed of two apical and two basal spines that arise from each end of a short median bar. This species does not have a tent-like shell at the proximal portion of the basal spines, which is commonly present in Devonian *Palaeoscenidium* such as *Palaeoscenidium cradophorum* Deflandre.

Range and occurrence: Upper Silurian to Lower Devonian. Fukuji and Hitoegane areas in the Hida-gaien terrane.

Genus *Goodbodium* Furutani 1990; emend. MacDonald 2004
Type species: *Palaeoscenidium flammatum* Goodbody 1986

Goodbodium flammatum (Goodbody 1986); emend. MacDonald 2004

Plate 2, figure 28

Goodbodium flammatum MACDONALD 2004, p. 260-261, figs. 2-1, 2; fig. 6-1. Eight rayed Palaeoscenidiidae GOODBODY 1982, pl. 2, fig. 15.

Palaeoscenidium (s.l.) sp. FURUTANI 1982, pl. 1, fig. 2.

Palaeoscenidium flammatum GOODBODY 1986, p. 152, pl. 1, figs. 1-4. - AMON, BRAUN and IVANOV 1995, p. 7, pl. 2, fig. 6.

Goodbodium elegans FURUTANI 1990, p. 42-43, pl. 7, fig. 10; pl. 8, figs. 1-3. *Palaeoscenidium* sp. LI 1994, pl. 2, fig. 7.

Goodbodium sp. indet. NOBLE 1994, p. 37, pl. 5, figs. 5, 6.

Remarks: Furutani (1990) placed the present species, from the Fukuji area of the Hida-gaien terrane, within his newly proposed *Goodbodium elegans*. However, MacDonald (2004) noted that *G. elegans* is a junior synonym of *Palaeoscenidium flammatum*

Goodbody, and he used *Goodbodium flammatum* for this species. The holotype of *G. elegans* figured by Furutani (1990) is identical to *P. flammatum*. *Goodbodium* differs from *Palaeoscenidium* in having different morphologies for the basal spine and its accessory spinules, and I follow MacDonald's (2004) opinion. Although the Hitoegane specimen is very poorly preserved, the morphology of the proximal portion of the basal spines with dense spinules is assignable to this species. According to Furutani (1990), *Goodbodium nishiyamai* Furutani differs from the present species by possessing well-amalgamated spinules and a downward curving short apical spine, although some specimens he figured are similar to *G. flammatum*.

Range and occurrence: Lower Silurian to Lower Devonian. Fukuji and Hitoegane areas in the Hida-gaien terrane; Mayila area in west Junggar, China; Marathon uplift in west Texas; Southern Urals; Cornwallis Island, Arctic Canada.

Genus *Palaeoephippium* Goodbody 1986

Type species: *Palaeoephippium bifurcum* Goodbody 1986

Palaeoephippium fukujiensis Furutani 1990

Plate 2, figure 26

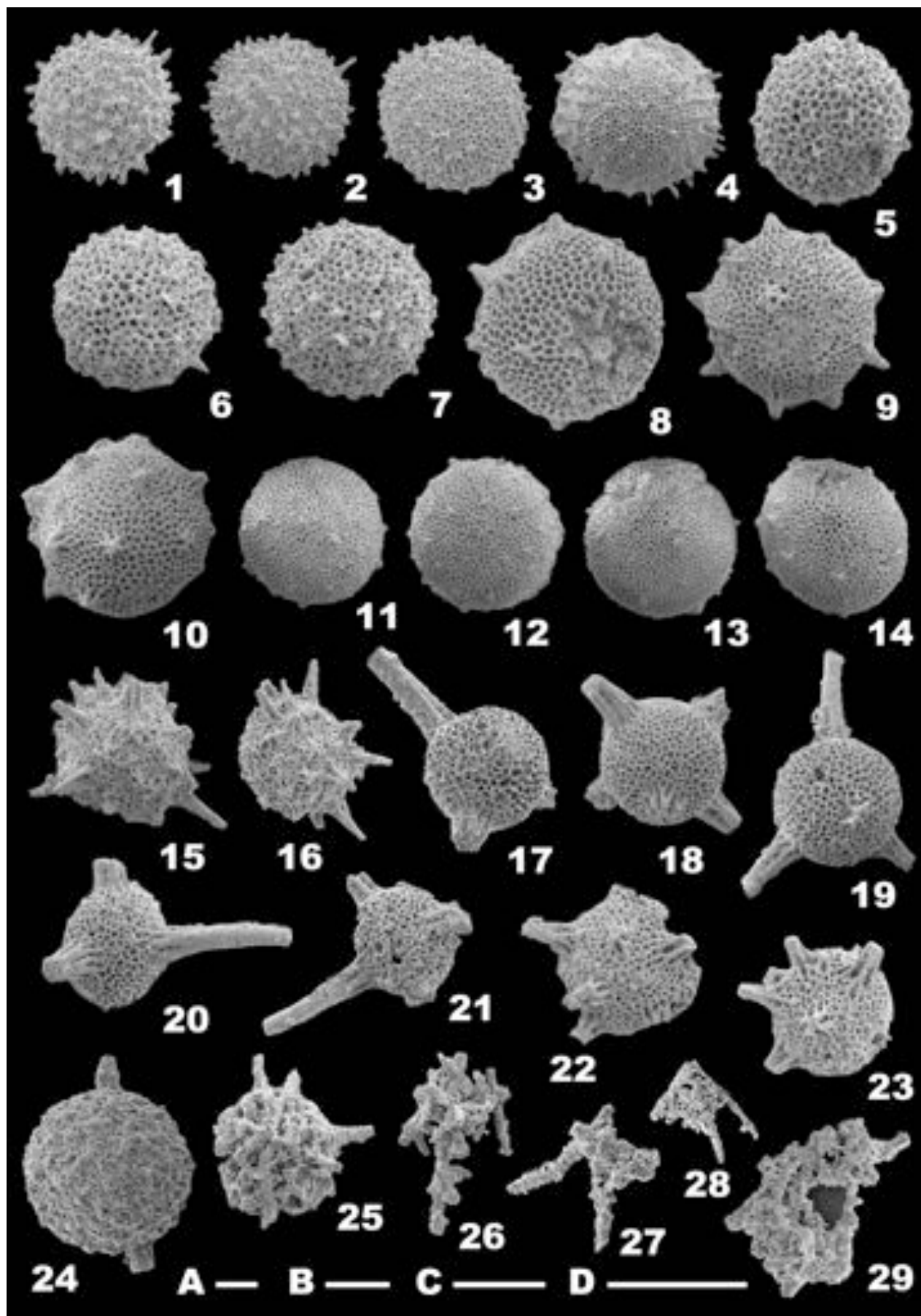
Palaeoephippium fukujiensis FURUTANI 1990, p. 46, pl. 9, figs. 2, 3.

Remarks: Specimens characteristically have a basic skeleton consisting of one apical and two basal spines arising from each end of a short median bar. In addition, the basal spine has small spinules at several levels. These characteristics are assigned to *Palaeoephippium fukujiensis* Furutani. This species is superficially similar to *Palaeoephippium echinatum* Goodbody, which was described from the Cape Phillips Formation of the Canadian Arctic Archipelago by Goodbody (1986). As to a comparison

PLATE 2

Scale bars, A to D, equal to 100 µm: A applies to 1-4, 11-14, B to 8-10, 15-23, C to 5-7, 24, 26, 28, D to 25, 27, 29.

- | | |
|---|---|
| <p>1-4 <i>Zadrappolus spinosus</i> Furutani. 1, sample ht-112704, IGUT-TK2946; 2, sample ht-1 12703, IGUT-TK2779; 3, sample ht-1 12703, IGUT-TK2793; 4, sample ht-1 12704, IGUT-TK301 8</p> <p>5-7 <i>Zadrappolus hitoeganensis</i> Furutani. 5, sample ht-112702, IGUT-TK2517; 6, sample ht-112706, IGUT-TK3396; 7, sample ht-112706, IGUT-TK3343ht-1 12703, IGUT-TK3612; 10, sample ht-1 12703, IGUT-TK3679</p> <p>11-14 <i>Zadrappolus</i> (?) <i>nudus</i> Kurihara, n. sp., 11, Paratype, sample ht-1 12705, IGUT-TK3 177; 12, Holotype, sample ht-112705, IGUT-TK3 199; 13, Paratype, sample ht-112713, IGUT-TK3676; 14, Paratype, sample ht-112713, IGUT-TK3699</p> <p>15,16 <i>Zadrappolus</i> (?) sp. 15, sample ht-112704, IGUT-TK2959; 16, sample ht-112704, IGUT-TK2955</p> <p>17-21 <i>Futobari solidus</i> Furutani. 17, sample ht-112713, IGUT-TK3549; 18, sample ht-112713, IGUT-TK3637; 19, sample ht-112713, IGUT-TK3624; 20,</p> | <p>sample ht-112713, IGUT-TK3710; 21, sample ht-081504, IGUT-TK4873</p> <p>22,23 <i>Futobari morishitai</i> Furutani. 22, sample ht-112706, IGUT-TK3354; 23, sample ht- 112706, IGUT-TK3448</p> <p>24 <i>Praespongocoelia parva</i> (Furutani), sample ht-112702, IGUT-TK2526</p> <p>25 <i>Rotasphaera</i> sp., sample ht-112705, IGUT-TK3310</p> <p>26 <i>Palaeoephippium fukujiensis</i> Furutani, sample ht-112705, IGUT-TK3 167</p> <p>27 <i>Palaeoscenidium</i> sp., sample ht-112705, IGUT-TK3316</p> <p>28 <i>Goodbodium flammatum</i> (Goodbody), sample ht-112705, IGUT-TK3 204</p> <p>29 <i>Ceratoikiscum armiger</i> Furutani, sample ht-112705, IGUT-TK3325</p> |
|---|---|



between the species, Furutani (1990) noted that the shell of *P. fukujiensis* is definitely smaller than that of *P. echinatum*.

Range and occurrence: Upper Silurian to Lower Devonian. Fukuji and Hitoegane areas in the Hida-gaien terrane.

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