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Paleogene ostracodes from the Kishima Formation, Kishima Group, Saga Prefecture, southwestern Japan

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Abstract

The uppermost Eocene–lowermost Oligocene Kishima Formation, containing abundant Mazean molluscan fauna, is distributed in the Karatsu Coalfield of Saga Prefecture. The formation yields at least 12 ostracode species from muddy sandstones. The fossil ostracode assemblages consist chiefly of *Acanthocythereis volubilis*, *Eopaijenbochella sinensis*, *Munseyella simplex*, *Trachyleberis inouei* sp. nov., and *Cytherella* sp. They correlate with assemblages from outer- shelf deposits of the lowermost Oligocene Itanoura Formation in the Sakito–Matsushima Coalfield of Nagasaki Prefecture, which also yield a Mazean molluscan fauna. This suggests as follows: 1) Ostracode faunas from the uppermost Eocene–lowermost Oligocene Mazean Stage are characterized by *Cytherella* sp. associated with *A. volubilis*, *E. sinensis*, and *M. simplex*; 2) the muddy sandstones were deposited not in the upper sublittoral zone presumed by the previous studies on fossil molluscs, but in outer-shelf environments. The new species mentioned above is described herein.

Key words: Eocene–Oligocene, Itanoura Formation, Kishima Formation, Mazean Stage, Ostracoda

Introduction

The Kishima Formation is a Paleogene shallow-marine sequence in the Karatsu Coalfield of northwestern Kyushu, southwestern Japan (Fig. 1). The formation yields abundant macrofossils such as molluscs and decapods, which have been extensively (e.g. Nagao, 1927; Matsushita, 1949; Inoue, 1971, 1972; Karasawa, 1993; Karasawa and Fudouji, 2000). Previous studies on the molluscs and decapods discussed the depositional environment of the Kishima Formation and two differenct interpretations have been put forward (Inoue, 1971, 1972; Karasawa, 1993). Inoue (1971, 1972) examined molluscan fossils from the formation quantitatively and suggested that the formation had been deposited in the upper sublittoral zone, shallower than 100–120 m depth. On the contrary, Karasawa (1993), using fossil decapods from muddy sandstones of the formation, considered that the deposits were in the lower sublittoral zone.

Eocene–earliest Oligocene shallow-marine ostracodes in northwestern Kyushu, southwestern Japan, have been reported from the Eocene Okinoshima and Funazu Formations in the Takashima Coalfield (Yamaguchi, in press) and the Oligocene Itanoura Formation in the Sakito–Matsushima Coalfield (Yamaguchi, 2004). Both the coalfields are located in the Nishisonogi basin (Iwata and Kameo, 2001). The fossil ostracodes from the other basins have not been previously reported. The Kishima Formation falls near the Eocene/Oligocene boundary (Okada, 1992) and is situated in the Karatsu basin (Iwata and Kameo, 2001).

We report fossil ostracodes from the Kishima Formation, describe characters of ostracode faunas near the Eocene/Oligocene boundary in northwestern Kyushu, and discuss depositional environments of the formation.

Lithostratigraphy and geologic age

The Kishima Formation is part of the Kishima Group (Matsushita, 1949) and is distributed in the Karatsu Coalfield, Saga Prefecture (Fig. 1). The formation consists of muddy sandstones intercalated by sandstones (120–150 m thick). It overlies the Yoshinotani Formation of the Ouchi Group, which comprises of sandstone with lignite (80 m thick), while it is covered with the Karatsu Formation defined by Mizuno (1963), which has sandstones, tuffs, and mudstones (>500 m thick). The three formations have conformable relationships. The Kishima Formation yields macrofossils such as molluscs (Inoue, 1971, 1972) and decapods (Karasawa, 1993; Karasawa and Fudouji, 2000) and microfossils such as foraminifers (Nagahama and Suzuki, 1956; Murata, 1961) and calcareous nannofossils (Okada, 1992). It correlates with the Mazean molluscan Stage of Mizuno (1962, 1964) and the Sakitonian benthic foraminifer Stage of Murata (1961).

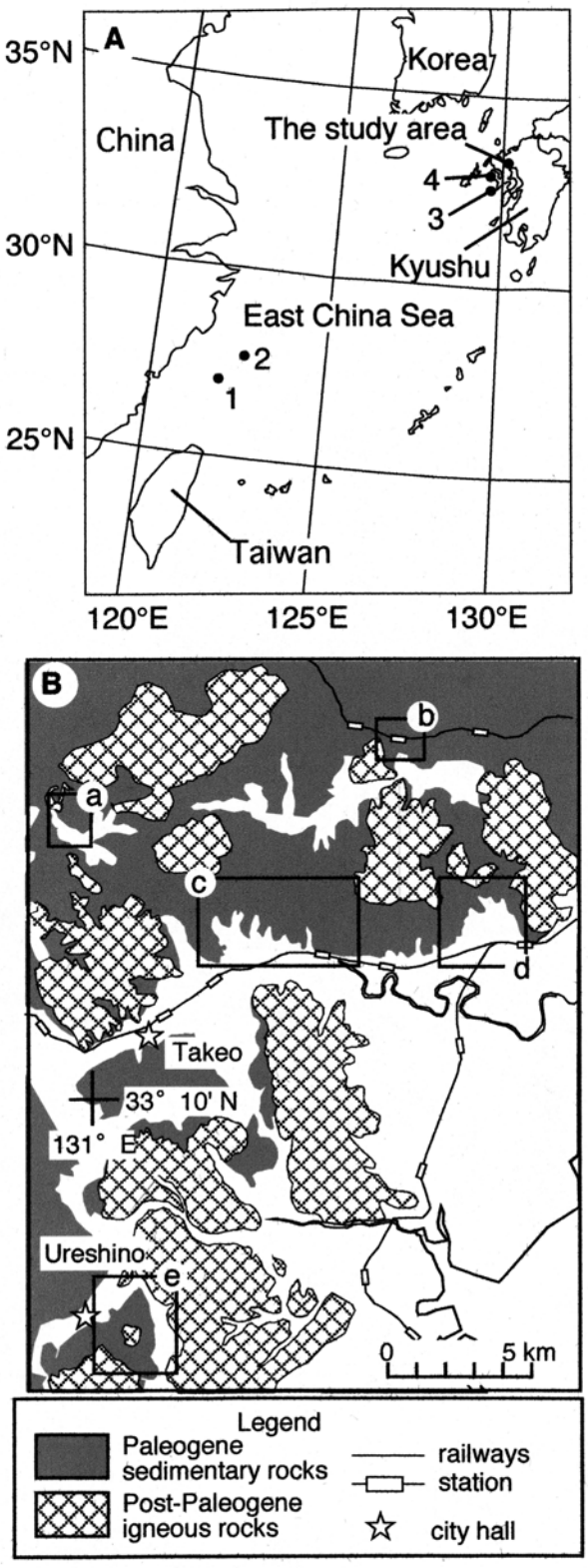

Fig. 1. A, Index map showing the study and discussion areas. 1, Eocene Oujiang Formation, 2, Eocene Oujiang and Wenzhou Formations, 3, Eocene Okinoshima and Funazu Formations, 4, Oligocene Itanoura Formation. B, Geologic map showing sampling sections in the study area. Partly modified after Saga Prefecture (1954). The sections a–e correspond with Figs. 3–5.

The geologic age of the Kishima Formation is assigned to either side of the Eocene/Oligocene boundary (33.9 Ma; Luterbacher et al., 2004), since the formation correlates with the calcareous nannofossil Subzone CP16a of Okada and Bukry (1980) (Okada, 1992; Fig. 2), spanning between 34.2 and 33.8 Ma (Luterbacher et al., 2004).

Material and Methods

Twenty-eight samples were collected from ten outcrops in Taku, Takeo, and Ureshino Cities, and Kitagata, Omachi, and Kouhoku Towns of Kishima County of Saga Prefecture (Figs. 3–5). Because sampling sections are separated by faults and a key bed was not found in the Kishima Formation, the sections can not be exactly correlated to each other.

To extract fossil ostracodes, 160 to 760 g of rock samples were disaggregated using a saturated sodium sulfate solution and naphtha. The disaggregated samples were washed through a 250 mesh (63 μm open) sieve. Larger fractions from the samples were dried by means of a homothermal oven. Fossil ostracode specimens were picked from the fractions coarser than 125 μm. Ostracode species were identified with a binocular microscope at 70 × magnification. Photographs were taken using a JEOL JSM-5310 Scanning Electron Microscope at the Department of Earth Sciences, Faculty of Science, Kanazawa University. Ostracode individuals were counted as the sum of the number of carapaces and the larger number of either left or right valves.

Fossil ostracode assemblages

Fossil ostracodes were found in ten out of the 28 samples (Table 1). The ten samples yielded one to two individuals per 100 g weight. Ostracode specimens consisted of many carapaces and a few valves. Many carapace specimens were abraded and deformed. Specimens from sample TKK01 were particularly poorly-preserved. The nine samples yielded at least 12 extinct species belonging to 11 extant genera. Only four of the nine samples yielded fossil ostracodes with more than 50 individuals. Fossil ostracode assemblages from these four samples (KMK01, KMK02, KSK02, and TKK01) were formed by *Eopaijenborchella sinensis* (Liu, 1989), accounting for 16–41% in each assemblage, *Acanthocythereis volubilis* (Liu, 1989) (4–76%), *Munseyella simplex* Chen *in* Yang et al., 1990 (0–43%), and *Trachyleberis inouei* sp. nov. (0–26%). These species were associated with *Cytherella* sp. (4–9%). The assemblages were composed of 3–8 species.

Discussion

Fossil ostracodes from the Kishima Formation share four common species with those from the Okinoshima, Funazu, and Itanoura Formations in the Nishisonogi basin: *Acanthocythereis volubilis*, *Abrocythereis* aff. *acrocaudalis* (Liu, 1989), *Eopaijenborchella*

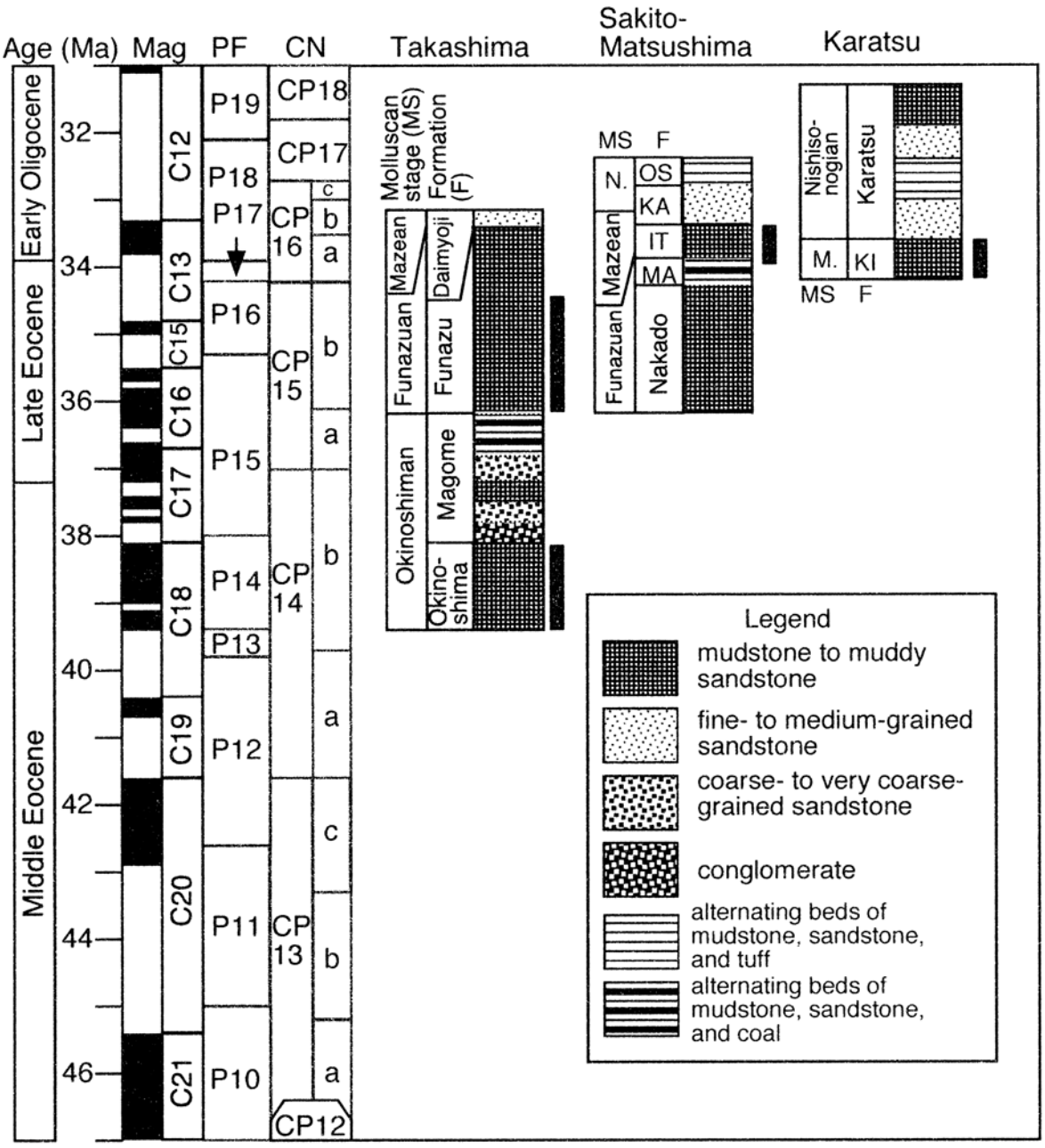

Fig. 2. Chronostratigraphy of the Kishima Group and the discussed formations. The chronostratigraphy refers to Okada (1992) and Yamaguchi et al. (2004). The magnetostratigraphy (Mag), planktic foraminifer (PF), and calcareous nannofossil (CN) zones are based on Ogg and Smith (2004), Berggern and Miller (1988), and Okada and Burky (1980), respectively. The time scale follows the geologic time scale 2004 (Luterbacher et al., 2004). Black bars represent formations bearing fossil ostracodes (Yamaguchi, 2004, in press; This study). Abbreviations: M = Mazean, N = Nishisonogian, IT = Itanoura, KA = Kakinoura, KI = Kishima, MA = Matsushima, and OS = Oshima.

sinensis, and *Munseyella simplex*. The fossil ostracode assemblages of the Okinoshima and Funazu Formations in the Takashima Coalfield are dominated by *A. volubilis*, *Cytherella elliptica* Liu, 1989, *E. sinensis*, and *Ambtonia*? sp. (Yamaguchi, in press). Biofacies A of the Itanoura Formation in the Sakito–Matsushima Coalfield is characterized by *E. sinensis* and *A. volubilis* (Yamaguchi, 2004). *Cytherella* sp. is not found in the Okinoshima and Funazu Formations, but it occurs in the Itanoura Formation. Thus the ostracode assemblage of the Kishima Formation, in particular the presence of *E. sinensis, A. volubilis* together with *Cytherella* sp., is most similar to that of Biofacies A of the Itanoura Formation.

Both the Kishima and Itanoura Formations correlate with the Mazean molluscan Stage, whereas the Okinoshima and Funazu Formations are typical stratigraphic units of the Okinoshiman and Funazuan molluscan Stages, respectively (Mizuno, 1964). Hence, *Cytherella* sp. is considered to be a characteristic species during the Mazean Age.

The genera *Acanthocythereis* and *Munseyella*, which live in warm currents, occur in modern shelve environments around southwestern Japan and the East China Sea, represented by the species *A.*

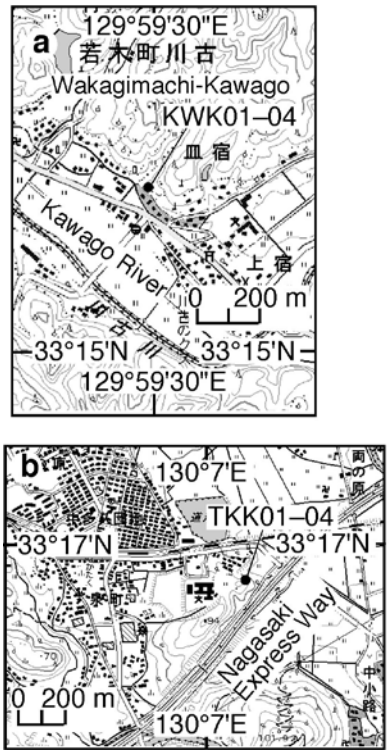

Fig. 3. Maps showing localities of rock samples in the sections a (Takeo City) and b (Taku City). The sections a and b refer to 1:25,000 "Taku" and "Imari" published by the Geographic Survey Institute of Japan, respectively.

munechikai, *M. japonica*, and *M. pupilla* (e.g. Ishizaki, 1981; Wang and Zhao, 1985; Ikeya and Suzuki, 1992; Zhou, 1995). *Trachyleberis* is also found in muddy and fine-grained sandy bottoms of modern shallow shelves in southwestern Japan and the East China Sea (e.g. Wang and Zhao, 1985; Ikeya and Suzuki, 1992; Zhou, 1995). The genera *Cytherella* and *Eopaijenborchella* occur from modern shelves and shelf slopes southward of Japan (e.g. Hanai et al., 1980). Taking into account the environmental requirements of living representatives of the ostracode genera and by examining planktic/total foraminifer ratios, lithofacies, and molluscan data, Yamaguchi (2004) considered that Biofacies A of the Itanoura Formation was deposited in an outer-shelf environment. Therefore the fossil assemblage from the Kishima Formation suggests a similar, outer-shelf environment.

Inoue (1971, 1972) recognized 11 fossil molluscan assemblages, which he examined quantitatively and used to suggest water depths at time of deposition of the Kishima Formation. He reported fossil molluscan assemblages dominated by *Cardium kishimaense* and *Pitar matsuraensis* from Yamaguchi of Kouhoku Town [sample nos. 7 and 8 of Inoue, (1971, 1972)]. The molluscan assemblages were named as the Mixture assemblages. The modern distribution of genera of the Mixture assemblages indicates the depth zone N2 of Oyama (1952), ranging at depths between 20–30 and 50–60 m (Inoue, 1971, 1972). The zone N2 correlates with shoreface or inner-shelf environments (Saito, 1989). The fossil ostracodes suggest deeper environments than the assessments of Inoue (1971, 1972). Muddy fine-grained sandstones including the fossil ostracodes yield fossil burrows and do not contain sedimentary structures that would indicate tidal or wave actions. The muddy sandstones are considered to have been deposited in calm condition sheltered from tidal/wave actions. In Yamaguchi of Kouhoku Town, the muddy sandstones are capped by a fine-grained and well-sorted sandstone of the Karatsu Formation. The sandstone has hummocky cross-stratification, indicating deposition in an inner-shelf or a shoreface environment, shallower than the storm wave-base (e.g. Saito, 1989) (Fig. 5). The muddy sandstones covered with inner-shelf/shoreface deposits are considered to be outer-shelf deposits (e.g. Saito, 1989). This is consistent with outer-shelf environments implied by the ostracodes. On the other hand, Karasawa (1993) reported the abundant occurrence of a decapode species *Collinsius simplex* from the other localities other than Yamaguchi, whose habitat had been the lower sublittoral zone. The view of Karasawa (1993) is consistent with the implication by the ostracodes.

Inoue (1972) considered that the *Turritella* assemblages from the Kishima Formation had inhabited the depth zones N0–N1, 0–30 m at water depths, and had been different from the Mixture assemblages in habitats, considering the modern biogeography and the mode of occurrence of the genus *Turritella*. As mentioned above, the ostracode assemblages associated with the Mixture assemblages from the Kishima Formation correlate with Biofacies A from the Itanoura Formation. Biofacies A yields the *Turritella* assemblages (Yamaguchi, 2004; Table 2). Hence, the Mixture assemblages as well as the *Turritella* assemblages had lived in outer-shelf environments during the Mazean Age. The Mixture assemblages might have dwelled at a similar water depth to the *Turritella* assemblages.

Summary

1. The Kishima Formation yields fossil ostracode assemblages dominated by *Acanthocythereis volubilis*, *Eopaijenborchella sinensis*, *Munseyella simplex*, and *Cytherella* sp., which correlate with Biofacies A of Yamaguchi (2004) from the Itanoura Formation in the Sakito–Matsushima Coalfield.
2. Fossil ostracodes from the Mazean molluscan Stage are characterized by *Cytherella* sp. which is associated with *A. volubilis*, *E. sinensis*, and *M. simplex*.
3. The Kishima Formation includes outer-shelf deposits.

Systematic description of selected taxa

(by T. Yamaguchi)

The terminology of description is based on Athersuch et al. (1989) and Horne et al. (2002). The classification other than generic ranks follows that of Hartmann and Puri (1974). Lengths and heights of specimens were measured with a micrometer ruler under a binocular microscope. All registered specimens are housed at the University Museum, University of Tokyo (Registered number: UMUT-

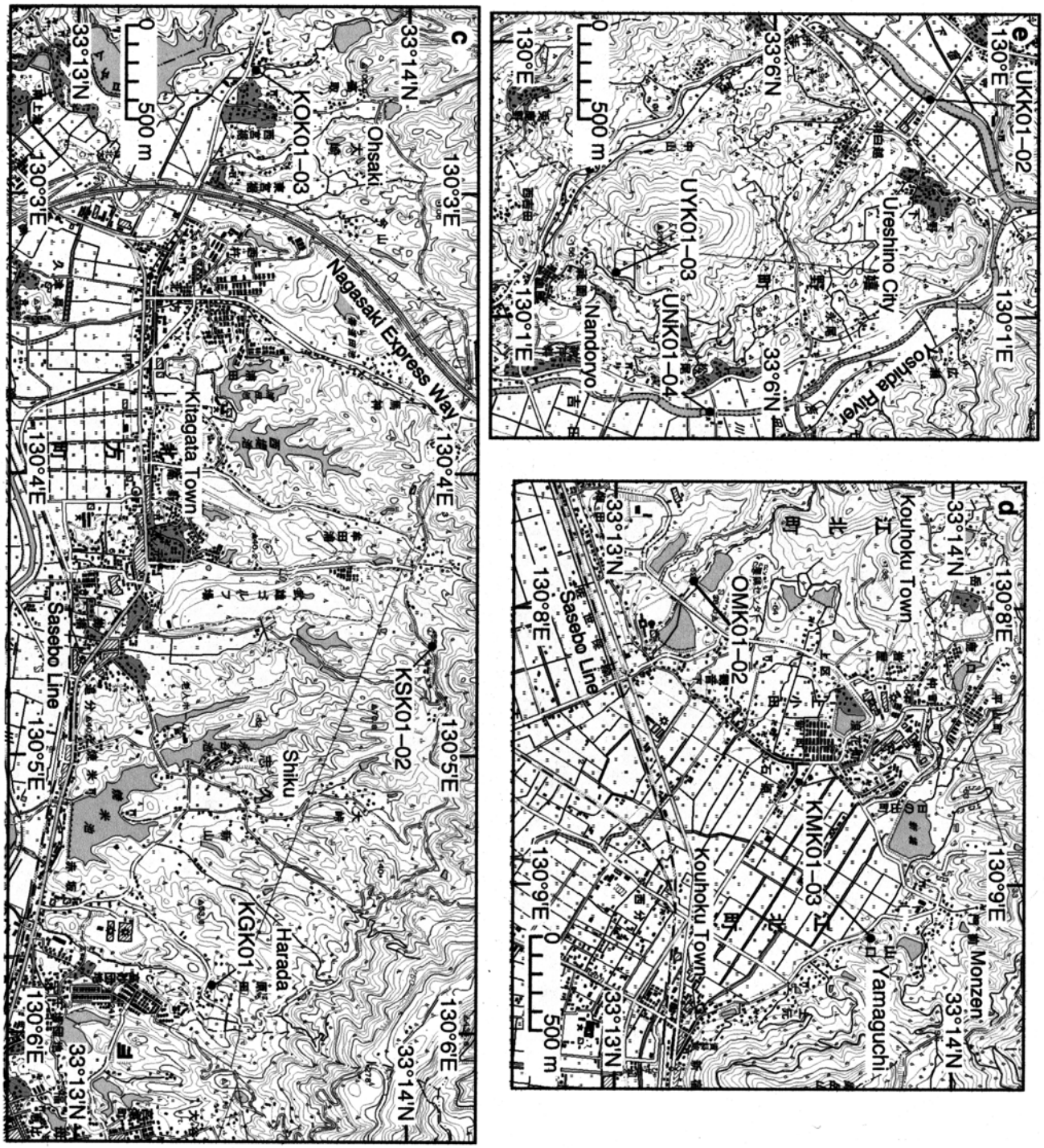

Fig. 4. Maps showing localities of rock samples in the sections c (Takeo City, Omachi and Kitagata Towns), d (Kouhoku Town), and e (Ureshino City). The sections c, d, and e refer to 1:25,000 "Kashima", "Ushizu", and "Takeo" published by the Geographic Institute of Japan, respectively.

CA29218–29225).

Suborder Platycopina Sars, 1866

Family Cytherellidae Sars, 1866

Genus *Cytherella* Jones, 1849

***Cytherella* sp.**

(Pl. 1, Figs. 1a–c)

2004 *Cytherella* sp.1; Yamaguchi, p. 65, 66, fig. 6.2.

Material: Two adult left-valves, two adult right-valves, and 19 adult carapaces, including UMUT-CA29218 (adult carapace, 0.70 mm long, 0.42 mm high) from KMK02.

Description: Carapace robust and large. Lateral outline elliptical:

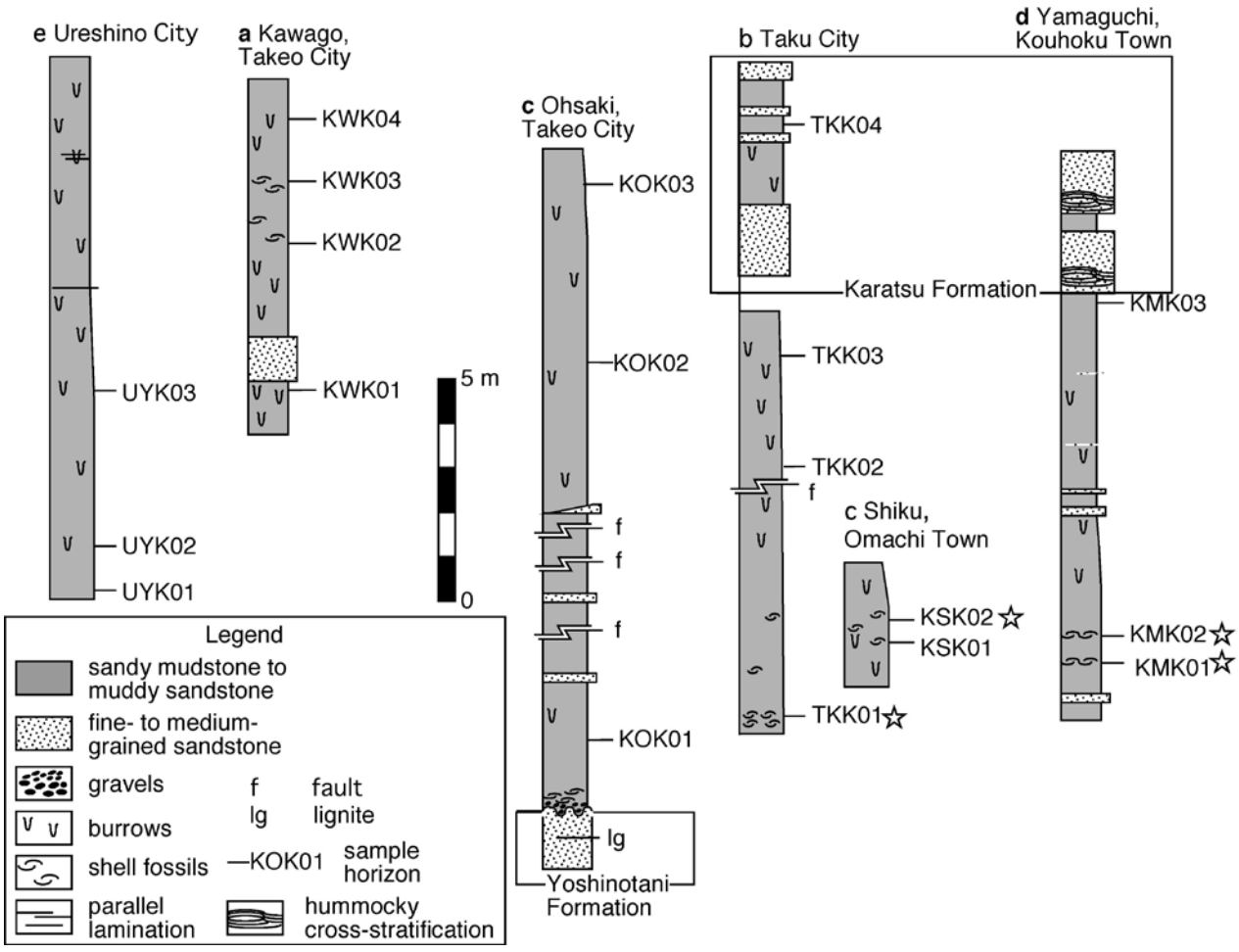

Fig. 5. Columns and sample horizons of the Kishima Formation. Stars indicate sample containing fossil ostracodes with more than 50 individuals.

anterior and posterior margins rounded; dorsal margin slightly curved; ventral margin curved; dorsal margin nearly parallel to ventral. Surface of carapace smooth. Dorsal outline elongated ovate; anterior end tapering; posterior end rounded; left and right margins slightly curved. Left valve larger than right.

Remarks: The specimens from the Kishima Formation were identified as *Cytherella* sp. 1 of Yamaguchi (2004), based on their tapering anterior margin in the dorsal view. The species is distinguished from *Cytherella elliptica* Liu, 1989, which occurs in the Eocene Oujiang Formation in the East China Sea and the Iojima Group in Nagasaki Prefecture (Liu, 1989; Yamaguchi, in press), by having a thinner and narrower carapace, and a more acute anterior margin in the dorsal view.

Occurrence: Oligocene: the Itanoura Formation in Nagasaki Prefecture (Yamaguchi, 2004) and the Kishima Formation in Saga Prefecture.

Suborder Podocopina Sars, 1866
Superfamily Cytheroidea Baird, 1850
Family Cytheridae Baird, 1850
Genus *Eopaijenborchella* Keij, 1966

***Eopaijenborchella sinensis* (Liu, 1989)**

(Pl. 1, Figs. 2a–c)

1989 *Paijenborchella sinensis* Liu, p. 151, pl. 167, figs. 1, 2.

1990 *Paijenborchella* (*Eopaijenborchella*) *sinensis* Liu; Yang et al., p. 374, 375, pl. 3, figs. 1–5.

2004 *Eopaijenborchella sinensis* (Liu); Yamaguchi, p. 68, fig. 7.2.

Material: One adult left-valve, two adult right-valves, and 72 adult carapaces, including UMUT-CA29219 (adult carapace, 0.73 mm long, 0.37 mm high) from KMK02.

Occurrence: Eocene: the Oujiang and Wenzhou Formations in the East China Sea (Liu, 1989; Yang et al., 1990), the Okinoshima and Funazu Formations in Nagasaki Prefecture (Yamaguchi, in press), Oligocene: the Itanoura Formation in Nagasaki Prefecture (Yamaguchi, 2004) and the Kishima Formation in Saga Prefecture.

Genus *Munseyella* van den Bold, 1957

***Munseyella simplex* Chen *in* Yang et al. 1990**

(Pl. 1, Figs. 3a– c)

1990 *Munseyella simplex* Chen *in* Yang et al., p. 374. 375, 386, pl. 1, figs. 7, 8.

2004 *Munseyella simplex* Chen; Yamaguchi, p. 69, fig. 7.4.

Material: 55 adult carapaces, including UMUT-CA29220 (adult carapace, 0.41 mm long, 0.21 mm high) from KMK02.

Occurrence: Eocene: the Wenzhou Formation in the East China Sea (Liu, 1989; Yang et al., 1990), the Okinoshima and Funazu Formations in Nagasaki Prefecture (Yamaguchi, in press), Oligocene: the Itanoura Formation in Nagasaki Prefecture (Yamaguchi, 2004) and the Kishima Formation in Saga Prefecture.

Family Trachyleberididae Sylvester-Bradley, 1948

Genus *Acanthocythereis* Howe, 1963

***Acanthocythereis volubilis* (Liu, 1989)**

(Pl. 1, Figs. 4a–c)

1989 *Trachyleberis volubilis* Liu, p. 154, pl. 168, figs. 12–16.
1990 *Trachyleberis volubilis* Liu; Yang et al., p. 377, pl. 2, figs. 1–3.
2004 *Acanthocythereis volubilis* (Liu); Yamaguchi, p. 67, fig. 6.1.

Material: 62 adult carapaces, including UMUT-CA29221 (male adult carapace, 0.77 mm long, 0.44 mm high) from KMK02.

Occurrence: Paleocene: the Linfeng Formation in the East China Sea (Liu, 1989), Eocene: the Oujiang and Wenzhou Formations in the East China Sea (Liu, 1989; Yang et al., 1990), the Okinoshima and Funazu Formations in Nagasaki Prefecture (Yamaguchi, in press), Oligocene: the Itanoura Formation in Nagasaki Prefecture (Yamaguchi, 2004) and the Kishima Formation in Saga Prefecture.

Genus *Trachyleberis* Brady, 1898

***Trachyleberis inouei* sp. nov.**

(Pl. 2, Figs. 1a–c, 2, 3a–b, 4a–b)

1990 *Trachyleberis lobuculus* Siddiqui; Yang et al., p. 376–377, 399, pl. I, fig. 4.

Types: Holotype, UMUT-CA29222, female adult carapace (0.69 mm long, 0.39 mm high) from sample KMK01; Paratypes, UMUT-CA29223, female adult carapace (0.70 mm long, 0.38 mm high) from sample KMK01; UMUT-CA29224, female adult carapace (0.66 mm long, 0.36 mm high) from sample KMK02; UMUT-CA29225, female left valve (0.65 mm long, 0.37 mm high) from sample KMK01.

Other material: Nine female adult carapaces from samples KMK01 and KMK02.

Type locality: In a cliff in Yamaguchi, Kouhoku Town, Kishima County (33°13’46”N, 130°9’9”E), a horizon 8.5 m below the Kishima/Karatsu Formational boundary.

Etymology: In honor of Dr. Eiji Inoue (ex - Geological Survey of Japan), who investigated molluscan fossils from the Kishima Formation.

Diagnosis: *Trachyleberis* characterized by well-developed reticulation and fainter carinae along the anterior margin.

Description: Carapace robust and medium to large. Lateral outline rectangular: anterior margin round; posterior margin tapering; dorsal margin straight; ventral margin slightly curved.

Surface ornament with reticulation, carinae, and tubercles. Reticulation in central area formed by polygonal and square muri. Carina present on anterodorsal area. Prominent murus running from anteroventral area and extended to ventral area. Three blunt tubercles along dorsal margin. Marginal denticles along posterior and anteroventral margins. Subcentral tubercle present but obscure. Eye tubercle prominent.

Dorsal outline lenticular. Left valve larger than right valve.

In internal view, amphidont-type hinge; one socket and one tooth of anterior element in left valve.

Measurements: Size of females range as follows: 0.65–0.72 mm in length, 0.35–0.39 mm in height, and 0.51–0.57 in height/length ratio.

Remarks: Generally, the genus *Trachyleberis* has distinctive sexual dimorphism in the carapace shape, but evidence of sexual dimorphism in the new species was not found in the examined material. In many *Trachyleberis* species, males can be distinguished from females by height/length ratios: Height/length ratios of males are less than approximately 0.51, while those of females are more than 0.51 (Table 3). Hence, all the examined material are considered to be female.

The specimen, which Yang et al. (1990) regarded as a juvenile of *T. lobuculus* Siddiqui, 1971, is identified as the new species, since it is identical with specimens from the Kishima Formation in the lateral outline, ornament, and reticulation pattern. The new species suggests a Paleogene biogeographic link between the East China Sea and Kyushu.

T. lobuculus, which was originally described from the Eocene deposits in western Pakistan, is distinguished from the new species by having larger eye tubercles and a double row of spines or tubercles in the posterior and anterior areas.

Trachyleberis leei Huh and Whatley, 1997, which was originally described from the Miocene Yeonil Group in southern Korea and found in the lower–middle Miocene Formations of central and northeastern Japan (e.g. Huh and Whatley, 1997; Yamada et al., 2001; Irizuki et al., 2004), is similar to the new species in the lateral outline and reticulation. However, it differs from the new species by having finer reticulation the central area, a blunter oblique carina in the anterodorsal area, and a blunter carina along the anteroventral margin.

Trachyleberis praeniitsumai Huh and Whatley, 1997 and *Trachyleberis mizunamiensis* Yajima, 1992, which were found in the early–middle Miocene deposits of central Japan and southern Korea (e.g. Yajima, 1992; Huh and Whatley, 1997; Irizuki et al., 2004) differ from the new species by having well-developed spinose reticulation and a blunter oblique carina in the anterodorsal area.

Trachyleberis awajiensis Yamaguchi *in* Yamaguchi et al. (2005), which was originally described from the Eocene Iwaya Formation in Hyogo Prefecture, southwestern Japan is distinguished from the new species by having blunter spines along the dorsal margin and a horizontal hollow across the middle of the carapace and in the

Table 1. The list of ostracode species from the Kishima Formation. Abbreviations: Ind = individual, C = carapace, L = left valve, and R = right valve.

Sample	KMK01				KMK02				KSK02				TKK01				OMK02			
Species	Ind	C	L	R	Ind	C	L	R	Ind	C	L	R	Ind	C	L	R	Ind	C	L	R
Abrocythereis aff. *acrocaudalis* (Liu, 1989)													1	1						
Acanthocythereis volubilis (Liu, 1989)	4	4			8	8			47	47										
Cytherella sp.	9	9			2	2			5	3	2	1	4	3		1	1	1		
Cytherelloidea spp.	1	1			1	1														
Cytheropteron sp.													2	2						
Eopaijenborchella sinensis (Liu, 1989)	40	40			14	13		1	10	10			7	6	1	1				
Eopaijenborchella sp.	2	2																		
Hanaiborchella sp.					1	1														
Krithe spp.	1	1																		
Munseyella simplex Chen *in* Yang et al., 1990	15	15			23	23							16	16						
Pacambocythere sp.					1	1							3	3						
Trachyleberis inouei Yamaguchi sp. nov.	25	25			4	3		1												
Trachyleberididae gen. et sp. indet.													23	23						
Gen. et sp. indet.																				
Total individuals	97				54				62				56				1			
Number of species	8				8				3				7				1			
Sample weight (g)	560				560				560				760				160			

posterior area.

Acanthocythereis volubilis is similar to the new species in the lateral outline and size, but distinguished from it by having spines in the anterior and central areas.

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Sample	UNK03				KOK01				UNK04				TKK03				UNK01			
Species	Ind	C	L	R	Ind	C	L	R	Ind	C	L	R	Ind	C	L	R	Ind	C	L	R
Abrocythereis aff. *acrocaudalis* (Liu, 1989)																				
Acanthocythereis volubilis (Liu, 1989)	1	1			1	1			1	1										
Cytherella sp.													1	1						
Cytherelloidea spp.	1	1															1	1		
Cytheropteron sp.																				
Eopaijenborchella sinensis (Liu, 1989)	2	2											1	1						
Eopaijenborchella sp.																				
Hanaiborchella sp.																				
Krithe spp.																				
Munseyella simplex Chen *in* Yang et al., 1990					1	1														
Pacambocythere sp.																				
Trachyleberis inouei Yamaguchi sp. nov.																				
Trachyleberididae gen. et sp. indet.																				
Gen. et sp. indet.																	1	1		
Total individuals	4				2				1				2				1			
Number of species	3				2				1				2				2			
Sample weight (g)	160				160				160				160				160			

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Table 2. Correlation between fossil ostracodes and molluscs from the Kishima and Itanoura Formations. Molluscan assemblages refer to Inoue (1964, 1971, 1972) and Hattori et al. (1993). Ostracodes based on Yamaguchi (2004) and the present study.

Molluscan assemblages and dominant species		Ostracodes Chracteristic species		Lithofacies	Depositional environments	
Itanoura Formation	Kishima Formation	Itanoura Formation	Kishima Formation		Yamaguchi (2004), This study	Inoue (1964, 1971, 1972)
<*Turritella* assemblage> *Turritella sakitoensis* *Turritella karatsuensis*		*Acanthocythereis volubilis* *Eopaijenborchella sinensis* *Munseyella simplex* *Abrocythereis* aff. *acrocaudalis* *Cytherella* sp.		muddy sandstone	outer shelf	N0-N1 (0 to 20–30 m at water depths)
	<Mixture assemblage> *Cardium kishimaense* *Pitar matsuraensis* *Saccella* sp. *Acila nagaoi*		*Trachyleberis inouei* sp. nov. *Eopaijenborchella sinensis* *Acanthocythereis volubilis* *Munseyella simplex* *Cytherella* sp.			N2 (20–30 to 50–60 m at water depths)
<"*Cardium*"-*Pitar* assemblage> "*Cardium*" *kishimaense* *Pitar maturaensis* *Crassatellites matsuraensis* *Dentalium ashiyaensis*		*Krithe* sp. *Palmoconcha oujiangensis* *Acanthocythereis volubilis*		mudstone		N1 (intertidal zone to 20–30 m at water depths)

Table 3. Sexual difference between length, height and height/length ratio in *Trachyleberis* species.

Species	Sex	Material	Length (mm)	Height (mm)	Height/length	Locality	Age	Reference
T. ishizakii	Male	4	0.869–0.921	0.419–0.447	0.475–0.514	Osaka Bay	Holocene	Yasuhara et al. (2002)
Yasuhara et al., 2002	Female	4	0.848–0.852	0.455–0.480	0.537–0.563	Osaka Bay	Holocene	Yasuhara et al. (2002)
T. leei Huh and Whatley, 1997	Male	1	0.75	0.38	0.51	South Korea	Miocene	Huh and Whatley (1997)
	Male	1	0.729	0.357	0.49	Gifu Pref.	Miocene	Irizuki et al. (2004)
	Female	5	0.73–0.75	0.39–0.42	0.54–0.57	South Korea	Miocene	Huh and Whatley (1997)
	Female	2	0.736–0.759	0.397–0.416	0.523–0.565	Gifu Pref.	Miocene	Irizuki et al. (2004)
T. mizunamiensis	Male	2	1.005–1.014	0.427–0.445	0.421–0.443	Gifu Pref.	Miocene	Irizuki et al. (2004)
Yajima, 1992	Female	2	0.856–0.865	0.441–0.473	0.515–0.547	Gifu Pref.	Miocene	Irizuki et al. (2004)
T. niitsumai	Male	1	0.88	0.36	0.41	Aomori Bay	Holocene	Ishizaki (1971)
Ishizaki, 1971	Male	1	0.84	0.35	0.42	Akita Pref.	Pleistocene	Ishizaki and Matoba (1985)
	Female	1	0.75	0.41	0.55	Aomori Bay	Holocene	Ishizaki (1971)
	Female	1	0.89	0.44	0.49	Shimane Pref.	Holocene	Ikeya and Suzuki (1992)
	Female	1	0.8	0.44	0.55	Kanagawa Pref.	Holocene	Irizuki et al. (1998)
	Female	1	0.83	0.44	0.53	Akita Pref.	Pleistocene	Ishizaki and Matoba (1985)
T. praeniitsumai Huh and Whatley, 1997	Female	5	0.76–0.80	0.41–0.44	0.53–0.58	South Korea	Miocene	Huh and Whatley (1997)
T. scabrocuneata (Brady, 1880)	Male	1	1.10	0.52	0.47	Setouchi Inland Sea	Holocene	Harding and Sylvester-Bradley (1953)
			90					
	Male	2	1.02–1.04	0.44–0.46	0.42–0.45	Osaka Bay	Holocene	Yasuhara and Irizuki (2001)
	Male	1	0.85	0.39	0.46	Shimane Pref.	Holocene	Ikeya and Suzuki (1992)
	Female	1	0.90	0.46	0.51	Setouchi Inland Sea	Holocene	Harding and Sylvester-Bradley (1953)
	Female	2	0.90–0.92	0.46–0.52	0.51–0.57	Osaka Bay	Holocene	Yasuhara and Irizuki (2001)
	Female	1	0.98	0.53	0.54	Kanagawa Pref.	Holocene	Irizuki et al. (1998)

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Plate 1

All scale bars indicate 0.10 mm. Arrows indicate anterior directions.

Fig. 1. *Cytherella* sp., UMUT-CA29218, adult carapace, KMK01.
1a. Left lateral view.
1b. Right lateral view.
1c. Dorsal view.

Fig. 2. *Eopaijenborcehlla sinensis* (Liu, 1989), UMUT-CA29219, adult carapace, KMK02
2a. Left lateral view.
2b. Right lateral view.

Fig. 3. *Munseyella simplex* Chen *in* Yang et al., 1990, UMUT-CA29220, adult carapace, KMK01
3a. Left lateral view.
3b. Right lateral view.
3c. Dorsal view.

Fig. 4. *Acanthocythereis volubilis* (Liu, 1989), UMUT-CA29221, adult carapace, KMK01

Plate 1

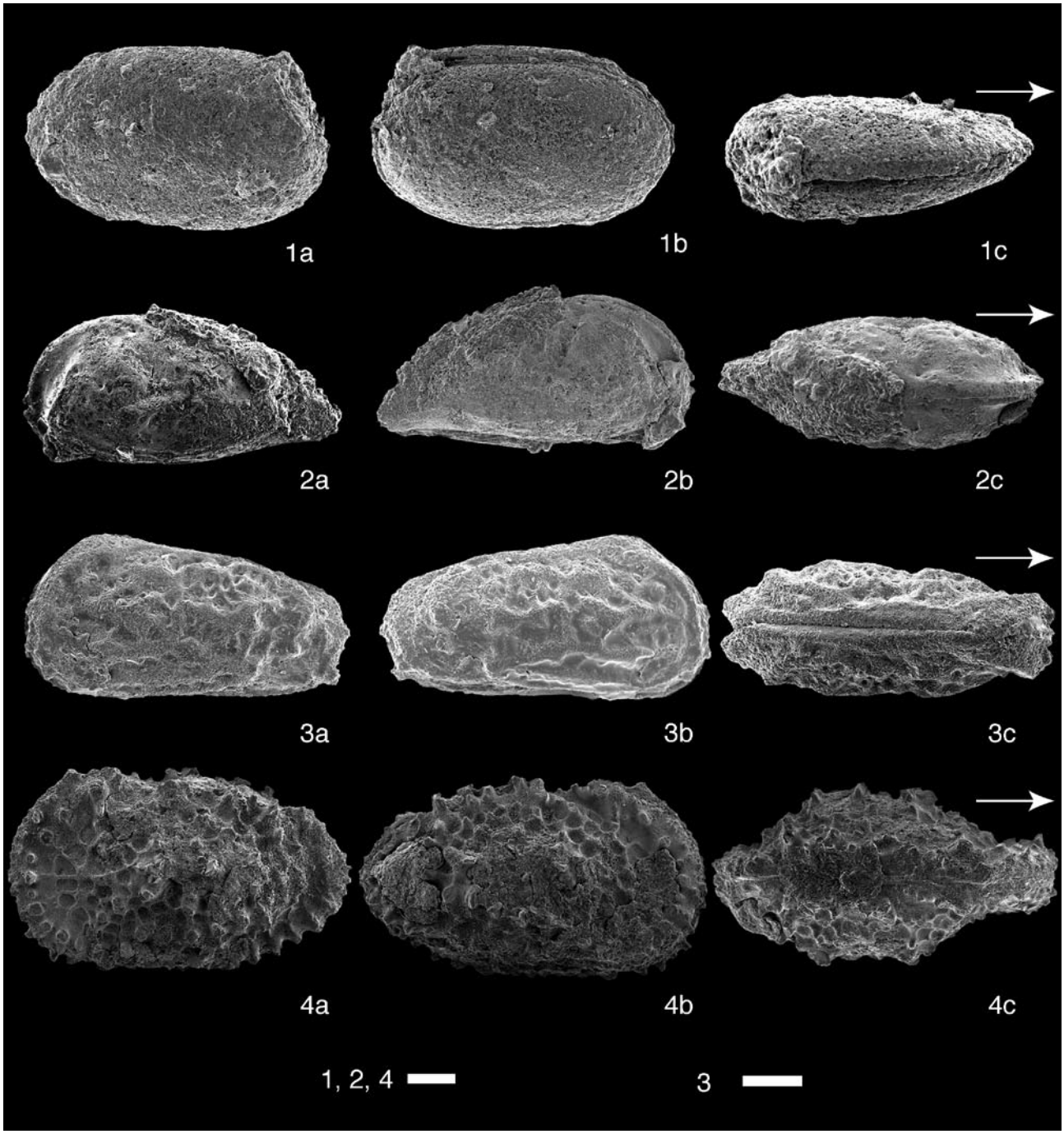

Plate 2

A scale bar indicates 0.10 mm. An arrow indicates an anterior direction.

Figs. 1–4. *Trachyleberis inouei* Yamaguchi sp. nov.

Fig. 1. Holotype, UMUT-CA29222, female carapace, KMK01.

1a. Left lateral view.

1b. Right lateral view.

1c. Dorsal view.

Fig. 2. Paratype, UMUT-CA29223, female carapace, KMK01, right lateral view.

Fig. 3. Paratype, UMUT-CA29224, female carapace, KMK02.

3a. Left lateral view.

3b. Right lateral view.

Fig. 4. Paratype, UMUT-CA29225, female left valve, KMK02.

4a. External view.

4b. Internal view.

Plate 2