Paleontological Research, vol. 6, no. 1, pp. 1-22, April 30, 2002

Middle Miocene ostracods from the Fujina Formation, Shimane Prefecture, Southwest Japan and their paleoenvironmental significance

GENGO TANAKA[1], KOJI SETO[2], TAKAO MUKUDA[3] AND YUSUKE NAKANO[4]

[1]*Graduate School of Science and Engineering, Shizuoka University, Shizuoka, 422-8529, Japan*

[2]*Department of Geoscience, Shimane University, Matsue, 690-8504, Japan (e-mail: seto@riko.shimane-u.ac.jp)*

[3]*Graduate School of Integrated Arts and Sciences, Hiroshima University, Higashi-Hiroshima, 739-8521, Japan (e-mail: takaom@hiroshima-u.ac.jp)*

[4]*Okehazama 4-59-226, Arimatsu-cho, Midoriku, Nagoya, 458-0911, Japan (e-mail: y-nakano@chikyumaru.co.jp)*

Received 16 August 2001; Revised manuscript accepted 8 November 2001

Abstract. Thirty-five ostracod species belonging to 18 genera are recognized from the Middle Miocene Fujina Formation (ca. 14-12 Ma), 3 km southwest of Matsue City, Shimane Prefecture, Japan. Most of these species are part of the recent Japan Sea proper water fauna; they are also classified into 4 categories, circumpolar, cryophilic, endemic cool-temperate and temperate species. These ostracod assemblages indicate that the Fujina Formation was deposited under a cold-water environment. Ten new species, *Ambtonia shimanensis*, *A. takayasui*, *Acanthocythereis fujinaensis*, *A. izumoensis*, *Cluthia tamayuensis*, *C. subjaponica*, *Kotoracythere tsukagoshii*, *Laperousecythere ikeyai*, *Palmoconcha irizukii*, and *Robertsonites yatsukanus* are described.

Key words: Fujina Formation, Japan Sea proper water, Middle Miocene, ostracods, paleoenvironment

Introduction

The Japan Sea developed as a result of back-arc spreading prior to 16 Ma and then further expanded by clockwise rotation of the southwestern part of the Japanese islands beginning 15 Ma (Otofuji and Matsuda, 1984). During this short period (ca. 16.5-15 Ma), a tropical to subtropical molluscan fauna, called the Kadonosawa Fauna, spread widely around the Japanese islands. At about 15 Ma, this Kadonosawa fauna was replaced by a cool to temperate molluscan fauna, the Shiobara-Yama type fauna in the Japan Sea region (Chinzei, 1986). According to Chinzei (1986), this drastic faunal change in molluscs was caused by the closure of the Tsushima Straits in the western portion of the Japan Sea. Based on studies of molluscan assemblages in the Middle Miocene of the San'in district along the Japan Sea, the shallow embayment facies (the Shiobara Fauna) appeared after the Omori period (ca. 14.5-15 Ma). During the Fujina period (ca. 14-12 Ma), the molluscan assemblages were accompanied by an offshore facies (the Yama Fauna) and an increase in colder species of the Shiobara Fauna (Takayasu *et al.*, 1992). Thus, it is thought that the Fujina Formation was deposited under a cold-water environment which resulted from the closure of the Tsushima Straits. However, the presence of warm-water cephalopod species (*Aturia* sp. and *Argonauta tokunagai*) in several horizons may suggest the influence of a warm-water current (Sakumoto *et al.*, 1996).

Because benthic ostracods do not have a pelagic life stage, they can be easily isolated by environmental barriers. Although Miocene ostracod assemblages in Japan have been reported from several localities (Ishizaki, 1963, 1966; Yajima, 1988, 1992; Irizuki, 1994; Irizuki and Matsubara, 1994, 1995; Ishizaki *et al.*, 1996; Irizuki *et al.*, 1998), the one report from the marine sediments in the southwest of Japan only covered the early Middle Miocene Bihoku Group (Yajima, 1988). To describe the ostracod assemblages in the Fujina Formation, therefore, it is very important to consider marine paleoenvironments of the Japan Sea coast and to examine their paleoenvironmental significance.

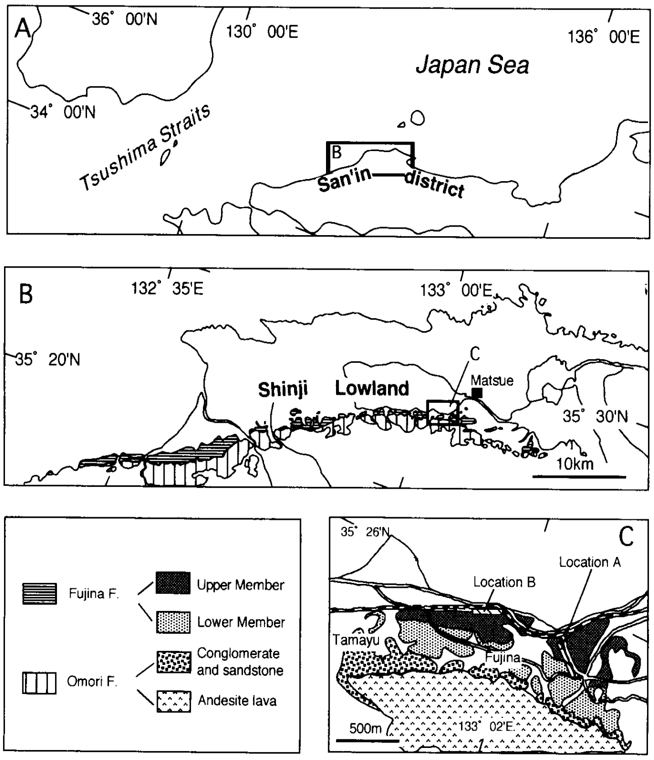


Figure 1. Map of the study area.

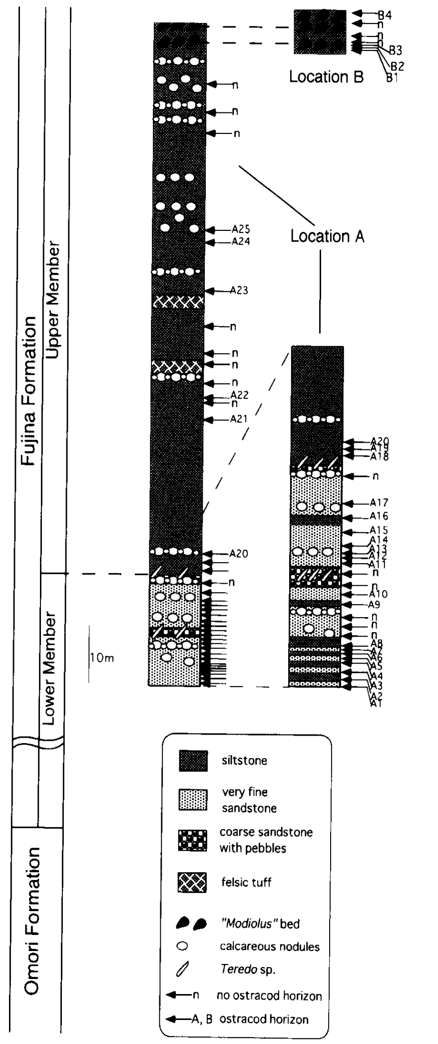


Figure 2. Columnar sections of the Fujina Formation.

Geological setting of Fujina Formation

The Fujina Formation was named by Tomita and Sakai (1937), then redefined by Ogasawara and Nomura (1980) and Takayasu and Nakamura (1984). This formation covers over 50 km, striking approximately EW to NE-SW and dipping about 10°N along the southern part of the Shinji Lowland (Figure 1). It is about 500 m in maximum thickness and conformably overlies the Omori Formation, which is composed of andesite lava in the lower part and shallow marine andesitic conglomerate and sandstone in the upper part (Kano *et al.*, 1994). The Fujina Formation near the type locality (this study area) is divided into the Lower and Upper Members by lithology. The Lower Member is composed of alternating layers of massive, gray, very fine-grained sandstone (0.5–5 m in thickness) containing calcareous nodules, and massive, dark gray siltstone (0.5–1 m in thickness). The sediments of the uppermost part of this member are made of a medium-grained sandstone (0.5 m in thickness) containing pebbles. The Upper Member is mainly composed of a massive, dark gray siltstone which is intercalated with felsic tuff layers (2 m in thickness), calcareous nodule beds, and "*Modiolus*" beds (0.3 m in thickness) in the uppermost part. Many marine molluscs, vertebrates (e.g., *Desmostylus japonicus* and *Carcharodon megalodon*) and decapods occur in all of the Fujina Formation (Kano *et al.*, 1994). Based on the planktonic foraminifers, the Upper Member of the Fujina Formation is assigned to N.10–11 of Blow's zones (14.6/14.8–12.4 Ma) (Nomura and Maiya, 1984).

Materials and methods

Fossiliferous sediment samples used in this study were collected from the upper part of the Lower Member to the Upper Member of the Fujina Formation at two locations (Figure 2). Each of the dried sediment samples (80 g) of a total of 46 collected were disaggregated, making use of naphtha for rock maceration (Maiya and Inoue, 1973), washing through a 235 mesh (63 μm) sieve, and drying again. This procedure was repeated until the whole sediment sample was disintegrated. A fraction coarser than 120 mesh (125 μm) sieve was sieved and all the ostracod specimens present were picked.

		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	B1	B2	B3	B4
	Ambtonia shimanensis sp. nov.											4				4	8		1		7									
++	*Ambtonia takayasui* sp. nov.							2				2								4										
--	*Acanthocythereis dunelmensis* (Norman, 1865)																						2	6	1	1	13	1	9	15
	Acanthocythereis fujinaensis sp. nov.								1			4		5																
	Acanthocythereis Izumoensis sp. nov.											5			8	10	8			2										
++	*Acanthocythereis koreana* Huh and Whatley, 1997	11							1		2	38	2	2	16	57	29	31	39	11	30									
-	*Acanthocythereis tsurugasakensis* Tabuki, 1986																										8	5		1
	Acanthocythereis sp.1											2									2									
	Acanthocythereis sp.2																				4								2	
+	*Callistocythere japonica uranipponica* Hanai, 1957																1													
+	*Callistocythere kyongjuensis* Huh & Whatley, 1997															2														
	Cluthia subjaponica sp. nov.											1							3		1									
	Cluthia tamayuensis sp. nov.	3						1								2	7		1		1									
	Cluthia sp.																										3			
	Cytheropteron sp.															11											2			
++	*Falsobuntonia taiwanica* Malz, 1982																		2		2									
	Kotoracythere tatsunokuchiensis Ishizaki, 1966											1																		
++	*Kotoracythere tsukagoshii* sp. nov.	44		1	2	6	5	8	13		6	4		2	5	37	13	11	9	3	15									
	Krithe sp.1																		1											
	Krithe sp.2															2	1		2											1
	Laperousecythere ikeyai sp. nov.					2						23	9	5	7	26	1	3	3	11										
	Laperousecythere sp.																													3
	Loxoconcha subkotoraforma Ishizaki, 1966	1																												
	Loxoconchidea sp.								1			2							2											
--	*Munseyella hatatatensis* Ishizaki, 1966																												1	
+	*Paijenborchella* cf. *tsurugasakensis* Tabuki, 1986	62				1				1	1	20		2		21	14	31	39	3	19						4	5	5	7
--	*Palmenella limicola* (Norman, 1865)	1						1				1			2	3	1	1	2	1										
++	*Palmoconcha irizukii* sp. nov.	2										8			1	39	31	31	33	6	52						1			
	Robertsonites japonicus (Ishizaki, 1966)	7	1			2			2			6					2													
-	*Robertsonites reticuliformus* (Ishizaki, 1966)								3			3			2	12		7	1	7	3	1								
--	*Robertsonites* cf. *tuberculatus* (Sars, 1866)																													2
	Robertsonites yatsukanus sp. nov.																							1			18	1	5	
	Robertsonites sp.																							1				3		1
	Semicytherura sp.																	1												
	Urocythereis pohangensis Huh and Whatley, 1997	29										10	5	6	11	22	9	5	8	7	5			3						
	No. of specimens	160	1	1	2	11	5	12	21	1	9	134	16	22	52	248	125	121	146	55	141	1	2	11	1	1	49	15	22	30
	No. of species	9	1	1	1	4	1	4	5	1	3	16	3	6	8	14	14	9	15	10	12	1	1	4	1	1	7	5	5	7
	Weight of Sediments (g)	1520	80	80	80	960	880	1440	1680	80	800	1120	320	320	1040	1680	1440	1440	1120	1040	1040	80	80	240	80	80	2240	1440	1680	1760

Figure 3. List of ostracod species from the Fujina Formation (– –: circumpolar species; –: cryophilic species; +: endemic cool-temperate species; ++: temperate species).

Characteristic ostracods from Fujina Formation

Thirty-five species in 18 genera of ostracods were identified from 29 samples (25 samples from Location A and 4 samples from Location B); (Figure 3). Ostracods from the Fujina Formation can be divided into four different temperature-related categories: 1) circumpolar, 2) cryophilic, 3) endemic cool-temperate and 4) temperate species. Cronin and Ikeya (1987) recognized 26 circumpolar and 21 cryophilic species from several Plio-Pleistocene formations of Japan. They referred to ostracods known from Recent and/or Cenozoic deposits of the North Atlantic and adjacent arctic seas as "circumpolar species", and species that typically occur with circumpolar species in Japanese deposits (in most cases being members of high-latitude genera) as "cryophilic species". Irizuki (1994) selected 13 circumpolar, 9 cryophilic and 4 endemic cold-water species from the Late Miocene Fujikotogawa Formation, Akita Prefecture, northern Japan. Irizuki and Matsubara (1995) described 5 circumpolar and 8 cryophilic species from the early Middle Miocene Suenomatsuyama Formation, Iwate Prefecture, northeastern Japan. They pointed out that circumpolar and cryophilic species preferred living in colder water than other species even during the Miocene. They also recognized 13 temperate species that preferred warmer waters than those mentioned as circumpolar and cryophilic indicators. The following 4 categories concern their (paleo) biogeographic distributions in the northern hemisphere and the relative water temperatures during deposition of the Fujina Formation.

1. Circumpolar species (4 species)

These species were widely distributed from middle- to high-latitude regions in the Miocene (Figure 4; regions 1–10), and dominate the upper horizons of the Fujina Formation. *Acanthocythereis dunelmensis* (Norman), *Munseyella hatatatensis* Ishizaki, *Palmenella limicola* (Norman) and *Robertsonites tuberculatus* (Sars).

2. Cryophilic species (2 species)

Since the Miocene, these species have been distributed around the Japanese islands (Figure 4; regions 5 and 9), and are prominent in the upper horizons of the Fujina Formation with the circumpolar species. *Acanthocythereis tsurugasakensis* Tabuki and *Robertsonites reticuliformus*

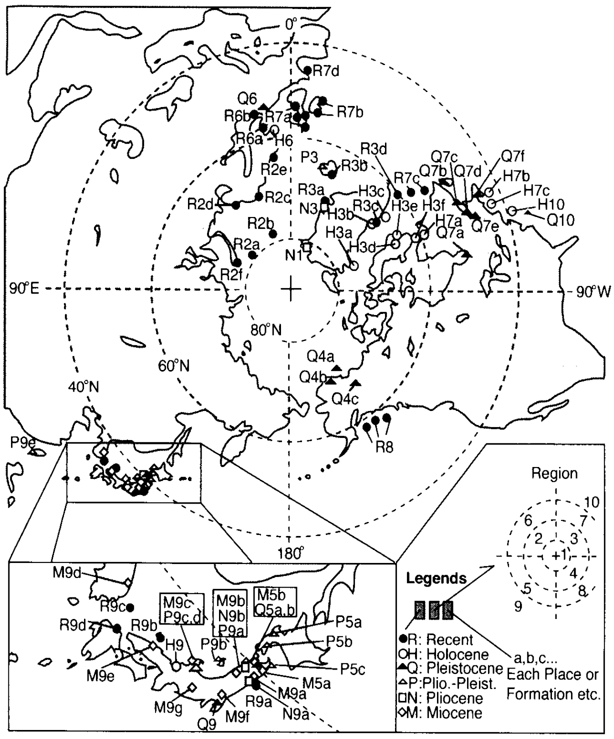


Figure 4. Geographic and stratigraphic distributions of characteristic species of the Fujina Formation. **R** [**2a**–**e**: Barents Sea (a-e: Elofson, 1941; b: Hartmann, 1992, 1993; c: Freiwald and Mostafawi, 1998); **2f**: Russian Harbour (Neale and Howe, 1975); **3a, b**: Greenland Sea (Elofson, 1941); **3c**: Baffin Bay (Elofson, 1941); **3d**: Labrador Sea (Hulings, 1967); **6a**: North Sea (Elofson, 1941; McKenzie *et al.*, 1989); **6b**: Baltic Sea (Elofson, 1941; Rosenfeld, 1977); **7a**: England (Elofson, 1941); **7b**: Ireland (Elofson, 1941); **7c**: Labrador Sea (Hulings, 1967); **7d**: Bay of Biscay (Caralp *et al.*, 1967; Caralp *et al.*, 1968); **8**: Gulf of Alaska (Brouwers, 1988, 1990); **9a**: Sendai Bay (Ikeya and Itoh, 1991); **9b**:off Shimane (Ikeya and Suzuki, 1992); **9c** : Ulleung Basin (Cheong *et al.*, 1986); **9d**: Fukuoka (Hanai, 1957a)]. **H** [**3a**–**c**:Baffin Bay (Neale and Howe, 1975); **3d**–**f** Baffin Island (Neale and Howe, 1975); **6**: Sandnes Clay (Lord, 1980); **7a**: Labrador Sea (Neale and Howe, 1975); **7b, c**: off Nova Scotia (Neale and Howe, 1975); **9**: Takahama shell bed (Kamiya and Nakagawa, 1993); **10**: off NewYork (Neale and Howe, 1975)]. **Q** [4a: Prudhoe Bay Boreholes (McDougall, Brouwers and Smith, 1986); **4b, c**: Gubik F. (Swain, 1961, 1963); **5a**: Wakimoto F. (Cronin and Ikeya, 1987); **5b**: Sasaoka F. (Cronin and Ikeya, 1987); **6**: Esbjerg deposit (Bassiouni, 1965); **7a**: Tyrrel Sea F. (Cronin, 1989); **7b, c**: East Goldthwait Sea F. (Cronin, 1989); **7d, e**: St. Lawrence Lowland (Cronin, 1981); **9**: Shimosa G. (Yajima, 1982; Yajima and Lord, 1990; Ozawa *et al.*, 1995); **10**: off NewYork (Neale and Howe, 1975)]. **P** [**3**: Tjornes Beds (Cronin, 1991); **5a**: Setana F. (Cronin and Ikeya, 1987); **5b**: Tomikawa F. (Cronin and Ikeya, 1987); **5c**: Daishaka F. (Tabuki, 1986); **9a**: Kitaura F. (Cronin and Ikeya, 1987); **9b**: Sawane F.(Cronin and Ikeya, 1987); **9c**: Junicho F. (Cronin and Ikeya, 1987); **9d**: Omma F. (Cronin and Ikeya, 1987; Kamiya *et al.*, 1996); **9e**: Ssukou F. (Malz, 1982)]. **N** [**1**: Kap Kobenhavn F. (Brouwers *et al.*, 1991; Penney, 1993); **3**: Lodin Elv F. (Penney, 1993); **9 a**: Tatsunokuchi F. (Ishizaki, 1966); **9b**: Tentokuji F. (Irizuki, 1996)]. **M** [**5a**: Kadonosawa F. (Irizuki and Matsubara, 1994); **5b**: Kamikoani F. (Yajima, 1988); **9a**: Hatatate F. (Ishizaki, 1966); **9b**: Fujikotogawa F. (Irizuki, 1994); **9c**: Togi Mud F. (Yajima, 1988); **9d**: Yeonil G. (Huh and Paik, 1992a,b; Huh and Whatley, 1997); **9e**: Fujina F. (This study); **9f**: Kobana F. (Irizuki *et al.*, 1998); **9g**: Shukunohora Sandstone (Yajima, 1988)].

(Ishizaki).

3. Endemic cool-temperate species (3 species)

These species are mainly distributed around the Japan Sea area from the Miocene to the Recent (Figure 4; regions 5 and 9), and occur throughout the Fujina Formation. *Callistocythere japonica uranipponica* Hanai, *C. kyongjuensis* Huh and Whatley and *Paijenborchella* cf. *tsurugasakensis* Tabuki. *C. japonica uranipponica* was recognized by Hanai (1957a) as a subspecies of *C. japonica*, and is restricted along the Japan Sea coast and the Pacific side of northern Japan after the Miocene. *C. kyongjuensis* was reported with some cold-water species in the Early Miocene Chunbuk Conglomerate Formation of Korea (Huh and Paik, 1992a,b). *P. tsurugasakensis* occurs in the Omma Formation (Late Pliocene to Early Pleistocene) with many warm- and a few cold-water species (Ozawa, 1996).

4. Temperate species (5 species, including 3 new species)

These have been distributed around the Japanese islands since the Miocene (Figure 4; regions 5 and 9), and dominate into the Lower Member to the lowermost part of the Upper Member of the Fujina Formation. *Acanthocythereis koreana* Huh and Whatley, *A. takayasui* Tanaka sp. nov., *Falsobuntonia taiwanica* Malz and *Kotoracythere tsukagoshii* Tanaka sp. nov. and *Palmoconcha irizukii* Tanaka sp. nov. *A. koreana* was first reported with cold-water species in the Early Miocene Chunbuk Conglomerate Formation of Korea (Huh and Paik, 1992a, b). *A. takayasui* has been reported in the Early Miocene from Mizunami, central Japan with some warm- and shallow-water species (as *F. taiwanica*; Yajima,1988, pl. 1, fig. 7), but this species occurred with some colder species in the Early Miocene of Korea (as *A. obai*; Huh and Paik, 1992a, pl. 2, fig. 14, and *F. taiwanica*; Huh and Paik, 1992b, pl. 2, fig. 14). *F. taiwanica*, *P. irizukii* and *K. tsukagoshii* occurs in horizons deposited under warm-water conditions of the Early-Middle Miocene Kadonosawa Formation, Iwate Prefecture, northeastern Japan (as *K.* sp.; Irizuki and Matsubara, 1994, pl. 1, fig. 3). *K. tsukagoshii* also occurs in the Omma Formation (Late Pliocene to Early Pleistocene) (as *Pectocythere quadrangulata*; Ozawa, 1996, pl. 8, fig. 2). Thus, it is probable that these temperate species adapted to colder environments during the Miocene in the Japan Sea area.

Discussion and conclusion

According to Ikeya and Cronin (1993), the Recent Japan Sea proper water is characterized by the ostracod species *A. dunelmensis*, *Elofsonella concinna*, *P. limicola*, *Robertsonites*, *Cluthia* and *Rabilimis*, and these species suggest cold-water isotherms along the upper slope at depths of

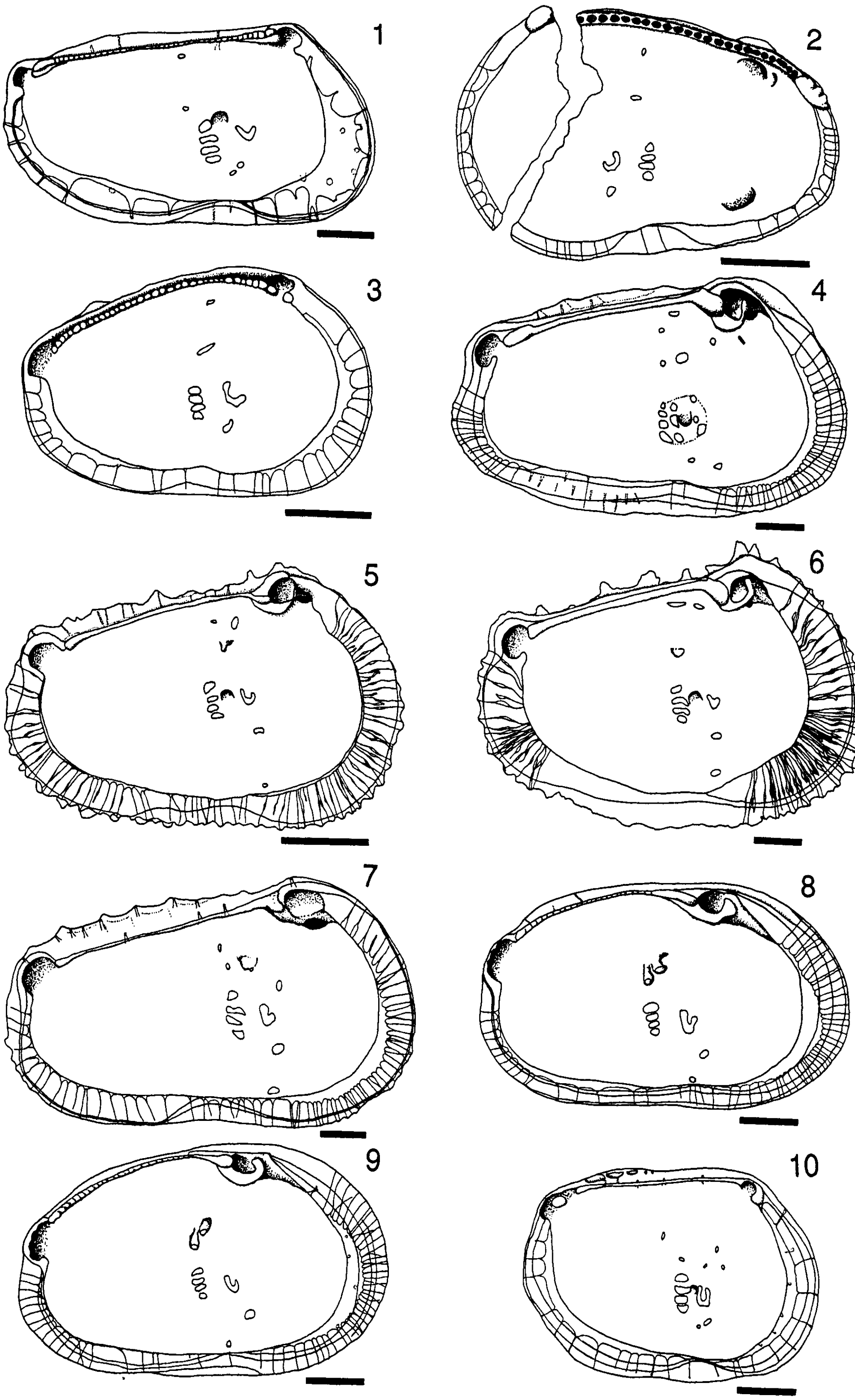
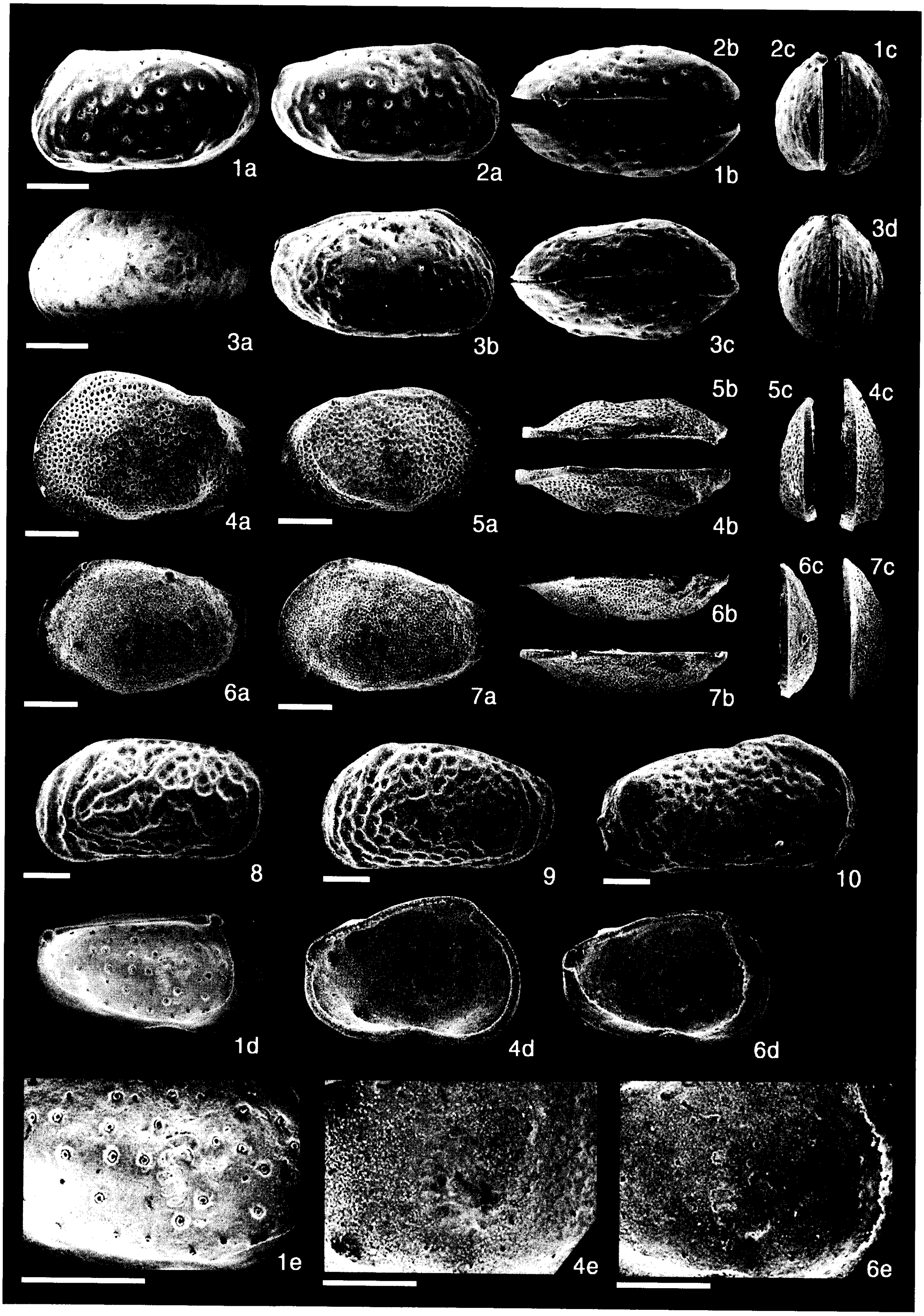


Figure 5. Internal views of each species. **1**: *Kotoracythere tsukagoshii* Tanaka sp. nov., female, LV, paratype, Loc. 1-A15, SUM-CO-1211; **2**: *Cluthia tamayuensis* Tanaka sp. nov., female, RV, paratype, Loc. 1-A1, SUM-CO-1217; **3**: *Cluthia subjaponica* Tanaka sp. nov., female, LV, paratype, Loc. 1-A15, SUM-CO-1220; **4**: *Laperousecythere ikeyai* Tanaka sp. nov., male, LV, paratype, Loc. 1-A11, SUM-CO-1229; **5**: *Acanthocythereis fujinaensis* Tanaka sp. nov.., female, LV, paratype, Loc. 1-A11, SUM-CO-1234; **6**: *Acanthocythereis izumoensis* Tanaka sp. nov., female, LV, paratype, Loc. 1-A17, SUM-CO-1239; **7**: *Robertsonites yatsukanus* Tanaka sp. nov., male, LV, paratype, Loc. 2-B1, SUM-CO-1249; **8**: *Ambtonia shimanensis* Tanaka sp. nov., LV, paratype, Loc. 1-A19, SUM-CO-1252; **9**: *Ambtonia takayasui* Tanaka sp. nov., female, LV, paratype, Loc. 1-A15, SUM-CO-1256; **10**: *Palmoconcha irizukii* Tanaka sp. nov., female, LV, paratype, Loc. 1-A15, SUM-CO-1261. Scale bar is 0.10 mm.


1a
2a
2b
1b
2c
1c
3a
3b
3c
3d
4a
5a
5b
4b
5c
4c
6a
7a
6b
7b
6c
7c
8
9
10
1d
4d
6d
1e
4e
6e

100–300 m. These assemblages resemble the Middle Miocene assemblage from the uppermost part of the Lower Member to the Upper Member of the Fujina Formation. Sakumoto *et al.* (1996) reported some cephalopod species that indicate that the paleo-Tsushima warm-water current flowed in the Proto-Japan Sea. Warmer conditions are indicated by the absence of cool-water ostracodes in part of this formation and the presence of prominent circumpolar and cryophilic species towards the upper horizons of the Fujina Formation, so we think that the Fujina Formation gradually became colder and colder towards the upper horizon, and that the warm-water current did not influence the benthic ostracods. Similar results have also been recognized from the benthic molluscan assemblages (Ogasawara and Nomura, 1980; Takayasu, 1986). Hence, it is concluded that during the early Middle Miocene period, temperate Pacific-side species invaded the coastal and offshore seafloor of the Japan Sea, and afterwards, with the change in marine climate and regional tectonic events, some taxa became isolated in embayments and offshore areas and adapted to cooler conditions.

Systematic descriptions
(by G. Tanaka)

All the illustrated specimens are deposited in the collections of the Shizuoka University Museum (SUM-CO-Number). Type locality of all new species is indicated by the index number: Loc. 1 or 2-horizon number; (Loc. 1: 35° 25.5′N, 133° 02.3′E; Loc. 2: 35° 25.6′N, 133° 01.4′E). Morphological terms follow the usage of Hanai (1961), Scott (1961) and Athersuch *et al.* (1989). The following abbreviations are used in this paper: C, carapace; RV, right valve; LV, left valve; L, length of valve; H, height of valve.

Order Podocopida Sars, 1866
Superfamily Cytheroidea Baird, 1850
Family Eucytheridae Puri, 1954
Subfamily Pectocytherinae Hanai, 1957
Genus ***Kotoracythere*** Ishizaki, 1966

Kotoracythere tsukagoshii Tanaka sp. nov.

Figures 5.1, 6.1–6.3

Kotoracythere sp. Irizuki and Matsubara, 1994, pl. 1, fig. 3.
Pectocythere quadangulata Hanai, Ozawa, 1996, pl. 8, fig. 2.

Etymology.—In honor of A. Tsukagoshi (Shizuoka University, Japan) a specialist in ostracod systematics.

Types.—Holotype, LV of male, SUM-CO-1208 (L = 0.66 mm, H = 0.32 mm). Paratypes, RV of male, SUM-CO-1209 (L = 0.67 mm, H = 0.32 mm); C of female, SUM-CO-1210 (L = 0.64 mm, H = 0.33 mm); LV of female, SUM-CO-1211 (L = 0.64 mm, H = 0.32 mm).

Type locality.—Loc. 1-A15.

Diagnosis.—Valve oblong box-shaped. Surface ornamented by scattered deep pits and very weak reticulations. Vestibule widely developed along anteroventral margin. Radial pore canals few. Anterior and posterior teeth of median element composed of upper and lower elements respectively.

Description.—Valve oblong box-shaped in lateral view. Anterior margin evenly rounded with infracurvature; dorsal margin straight, sloping gently toward posterior; posterior margin truncated dorsally and rounded ventrally; ventral margin nearly straight. Large sexual dimorphism; in lateral view, male forms more elongate; in dorsal view, female forms having inflated carapace in the posteroventral area. Eye spot not observed. Surface ornamented by scattered deep pits, which are the openings of normal pore canals, and very weak reticulation. In dorsal view, carapace is elongate ovate, widest in the posteromedian area, but compressed in the median area in female forms. In anterior view, carapace subovate, broadest at point near mid-height. Marginal zone broad anteriorly, vestibula widely developed in the anteroventral area and narrowly in the posteroventral area. Marginal pore canals few, 7 in anterior. 5 in posterior. Selvage well developed. Hinge pentodont: In LV, anterior and posterior elements are interiorly opened sockets respectively; median element is a crenulate bar with teeth at anterior and posterior terminations which are composed of upper and lower elements respectively. One V-shaped frontal scar. Four elliptical adductor scars are in a vertical row, the middle two are narrow. Two small elliptical mandibular scars. Two dorsal scars (one elliptical, dorsomedial; one elliptical, mid-dorsal). Prominent fulcral point.

Remarks.—This species differs from *K.* sp. widely reported from Plio-Pleistocene formations of north and central Japan (Ishizaki and Matoba, 1985; Tabuki, 1986; Cronin and Ikeya, 1987; Ozawa, 1996), in its very weak reticulation. The present species is distinguished from *Pectocythere tsiuensis* Brouwers, 1990 from the Quaternary

← **Figure 6.** **1–3**, *Kotoracythere tsukagoshii* Tanaka sp. nov. **1a–e**: male LV, holotype, Loc. 1-A15, SUM-CO-1208; **2a–c**: male RV, Loc. 1-A15, SUM-CO-1209; **3a–d**: female carapace, Loc. 1-A15, SUM-CO-1210. **4–5**, *Cluthia tamayuensis* Tanaka sp. nov. **4a–e**: female LV, holotype, Loc. 1-A16, SUM-CO-1215; **5a–c**: male RV, paratype, Loc. 1-A15, SUM-CO-1216. **6–7**, *Cluthia subjaponica* Tanaka sp. nov. **6a–e**: female LV, holotype, Loc. 1-A16, SUM-CO-1218; **7a–c**: male LV, paratype, Loc. 1-A15, SUM-CO-1219. **8**: *Callistocythere japonica uranipponica* Hanai, 1957, male LV, Loc. 1-A16, SUM-CO-1213. **9**: *Callistocythere kyongjuensis* Huh and Whatley, 1997, male LV, Loc. 1-A15, SUM-CO-1214. **10**: *Munseyella hatatatensis* Ishizaki, 1966, male RV, Loc. 2-B3, SUM-CO-1212. Scale bar is 0.10 mm.

sediments of the Gulf of Alaska, North America, in its very weak reticulation and the outline of the anterior margin.

Occurrences.—Early to Middle Miocene and Pleistocene sediments, Honshu, Japan (M5a, M9e and P9d; see Figure 4).

Genus ***Munseyella*** van den Bold, 1957

Munseyella hatatatensis Ishizaki, 1966

Figure 6.10

Munseyella hatatatensis Ishizaki, 1966, p. 153, pl. 19, fig. 2; Cronin and Ikeya, 1987, p. 76, pl. 3, fig. 16; Ikeya and Itoh, 1991, fig. 19A; Huh and Paik, 1992b, pl. 3, fig. 9; Irizuki, 1994, p. 8, pl. 1, fig. 2; Kamiya *et al.*, 1996, pl. 2, fig. 3; Ozawa, 1996, pl. 7, fig. 2.

Munseyella mananensis Hazel and Valentine, 1969, p. 749–751, pl. 97, figs. 19–24, pl. 98, figs. 1, 3, 4, 11, 12, text-figs. 4a, b, 5a, e, g; Cronin, 1989, pl. 2, fig. 8.

Remarks.—Cronin and Ikeya (1987) thought that *M. hatatatensis* was conspecific with *M. mananensis* Hazel and Valentine, 1969. Based on carapace morphology and geographical distribution, I have followed their opinion.

Occurrences.—Miocene to Recent sediments of North Atlantic, Japan and Korea (H3a–c, P5a, b, Q5b, Q7a, b, H7a–c, M9a, b, d, e, P9c, d, R9a, Q10, H10; see Figure 4).

Family Leptocytheridae Hanai, 1957
Genus ***Callistocythere*** Ruggieri, 1953

Callistocythere japonica uranipponica Hanai, 1957

Figure 6.8

Callistocythere japonica uranipponica Hanai, 1957a, p. 457–459, pl. 9, figs. 3a–c; Ishizaki and Matoba, 1985, pl. 2, fig. 8; Kamiya and Nakagawa, 1993, pl. 2, fig. 1.

Callistocythere cf. *japonica uranipponica* Hanai. Ishizaki, 1966, p. 147, pl. 16, fig. 13.

Remarks.—*C. japonica uranipponica* was recognized by Hanai (1957a) as a subspecies of *C. japonica*. *C. japonica uranipponica* is distinguished from *C. japonica* in having a more narrowly rounded posteroventral margin.

Occurrences.—Miocene to Recent sediments along the Japan Sea and the north Pacific areas of Japan (Q5b, M9e, N9a, H9, R9d; see Figure 4).

Callistocythere kyongjuensis Huh and Whatley, 1997

Figure 6.9

Callistocythere kyongjuensis Huh and Whatley, 1997, p. 32, 34, pl. 1, figs. 1–6.

Callistocythere sp. A Huh and Paik, 1992b, pl. 3, fig. 11.

Remarks.—This is the first reporting of *C. kyongjuensis* from Japan.

Occurrences.—Miocene sediments of the south Japan Sea side areas (M9d, e; see Figure 4).

Genus ***Cluthia*** Neale, 1973

Cluthia tamayuensis Tanaka sp. nov.

Figures 5.2, 6.4, 6.5

Etymology.—For the type locality in the town of Tamayu.

Types.—Holotype, LV, SUM-CO-1215 (L = 0.41 mm, H = 0.26 mm). Paratypes, RV of male, SUM-CO-1216 (L = 0.39 mm, H = 0.24 mm); RV of female, SUM-CO-1217 (L = 0.41 mm, H = 0.24 mm).

Type locality.—Loc. 1-A16.

Diagnosis.—alve subreniform. Anterior margin evenly rounded. Surface densely pitted with small, deep, polygonal pits. A mid-ventral carinal ridge runs toward the mid-posterior area. Radial pore canals (10 anteriorly; 10 posteriorly). Significant sexual dimorphism.

Description.—Valve subreniform in lateral view. Anterior margin evenly rounded; dorsal margin straight, sloping toward posterior; posterior margin straight (LV), truncate (RV); ventral margin concave. Large sexual dimorphism; in lateral view, male forms more elongate; in dorsal view, female forms inflated laterally. Eye spot not observed. Surface densely pitted with small, deep, polygonal pits. A carinal ridge occupies the mid-ventral area, runs toward the mid-posterior area. One tubercle developed in the posterodorsal area. In dorsal view, carapace appears compressed and subhexagonal; lateral outline sinuate, anterior end more pointed than posterior. In anterior view, carapace subpentagonal, broadest at the carinal ridge; anterior marginal rim strong. Marginal zone narrow, with narrow anterior and posterior vestibula. Marginal pore canals are straight and number 10 anteriorly; 12 ventrally; 10 posteriorly. Selvage well developed. Hinge entomodont: In RV, anterior element is an elliptical tooth; a crenulated median socket lies just below the smooth bar; posterior element is a well-developed toothplate. One very large U-shaped frontal scar. Four adductor scars in a vertical row (the uppermost and lowermost are semicircular, the middle two are elliptical). One semicircular mandibular scar. Two dorsal scars (one elongate dorsomedial; one semicircular mid-dorsal).

Remarks.—his species differs from *C. japonica* Tabuki, 1986 from the Plio-Pleistocene Daishaka Formation, northern Japan, in its posteriot outline,deep polygonal pits and the carinal ridge toward mid-posterior. The present species is distinguished from *C. ishizakii* Zhao, 1988 (MS) from the Late Pleistocene and Holocene drilling cores of the Okinawa Trough, East China Sea (in Ruan and Hao, 1988), in its lateral outline and deep polygonal pits.

Occurrence.—nly from the Fujina Formation (M9e; see Figure 4).

Cluthia subjaponica Tanaka sp. nov.

Figures 5.3, 6.6, 6.7

Etymology.—For its close resemblance with *Cluthia japonica* Tabuki.

Types.—olotype, LV of female, SUM-CO-1218 (L = 0.40 mm, H = 0.24 mm). Paratypes, LV of male, SUM-CO-1219 (L = 0.40 mm, H = 0.23mm); LV of female, SUM-CO-1220 (L = 0.40 mm, H = 0.24 mm).

Type locality.—Loc. 1-A16.

Diagnosis.—Valve subreniform. Anterior margin evenly rounded. Surface densely pitted with small, deep, round pits. Radial pore canals (23 anteriorly; 16 posteriorly). Prominent fulcral point. Sexual dimorphism weak.

Description.—Valve subreniform in lateral view. Anterior margin evenly rounded; dorsal margin straight, sloping toward posterior; posterior margin straight; ventral margin nearly straight to slightly convex. Sexual dimorphism weak. Eye spot not observed. Surface densely pitted with small, deep, round pits. One tubercle developed in the posterodorsal area. In dorsal view, lateral outline nearly straight; anterior end more pointed than posterior. In anterior view, LV arched, broadest at point near mid-height; anterior marginal rim strong. Marginal zone relatively broad, with narrow anterior and posterior vestibula. Marginal pore canals are straight, numbering 23 in anterior, 5 in ventral, 16 in posterior. Selvage well developed. Hinge entomodont: in LV, anterior and posterior elements are elongate sockets connected by a containant respectively; a cremulated median bar lies just below the containant. One very large U-shaped frontal scar. Four adductor scars in a vertical row (the uppermost one is semicircular, the lower three are elliptical). One circle mandibular scar. One elliptical dorsal scar mid-dorsally. Prominent fulcral point.

Remarks.—This species differs from *C. japonica* Tabuki, 1986 from the Plio-Pleistocene Daishaka Formation, the north Japan, in its lateral outline, small round pits and lack of tubercles in the posterodorsal and posteroventral areas.

Occurrence.—Only from the Fujina Formation (M9e; see Figure 4).

Subfamily Schizocytherinae Mandelstam, 1960
Tribe Paijenborchellini Deroo, 1966
Genus ***Paijenborchella*** Kingma, 1948

Paijenborchella cf. ***tsurugasakensis*** Tabuki, 1986

Figure 7.1, 7.2

Paijenborchella tsurugasakensis Tabuki, 1986, p.65-67, pl. 2, figs. 12-19, text-fig. 18-3; Kamiya *et al.*, 1996, pl. 3, fig. 3; Ozawa, 1996, pl. 7, fig. 8.

Remarks.—This species was first described from the Plio-Pleistocene Daishaka Formation, the north Japan by Tabuki (1986). Specimens from the Fujina Formation differ slightly from the type specimen, in the shape of posteroventral area.

Occurrence.—Miocene to Pleistocene sediments of Japan Sea side areas and northern Honshu, Japan (P5c, M9e and P9d; see Figure 4).

Genus ***Palmenella*** Hirschmann, 1916

Palmenella limicola (Norman, 1865)

Figure 7.3

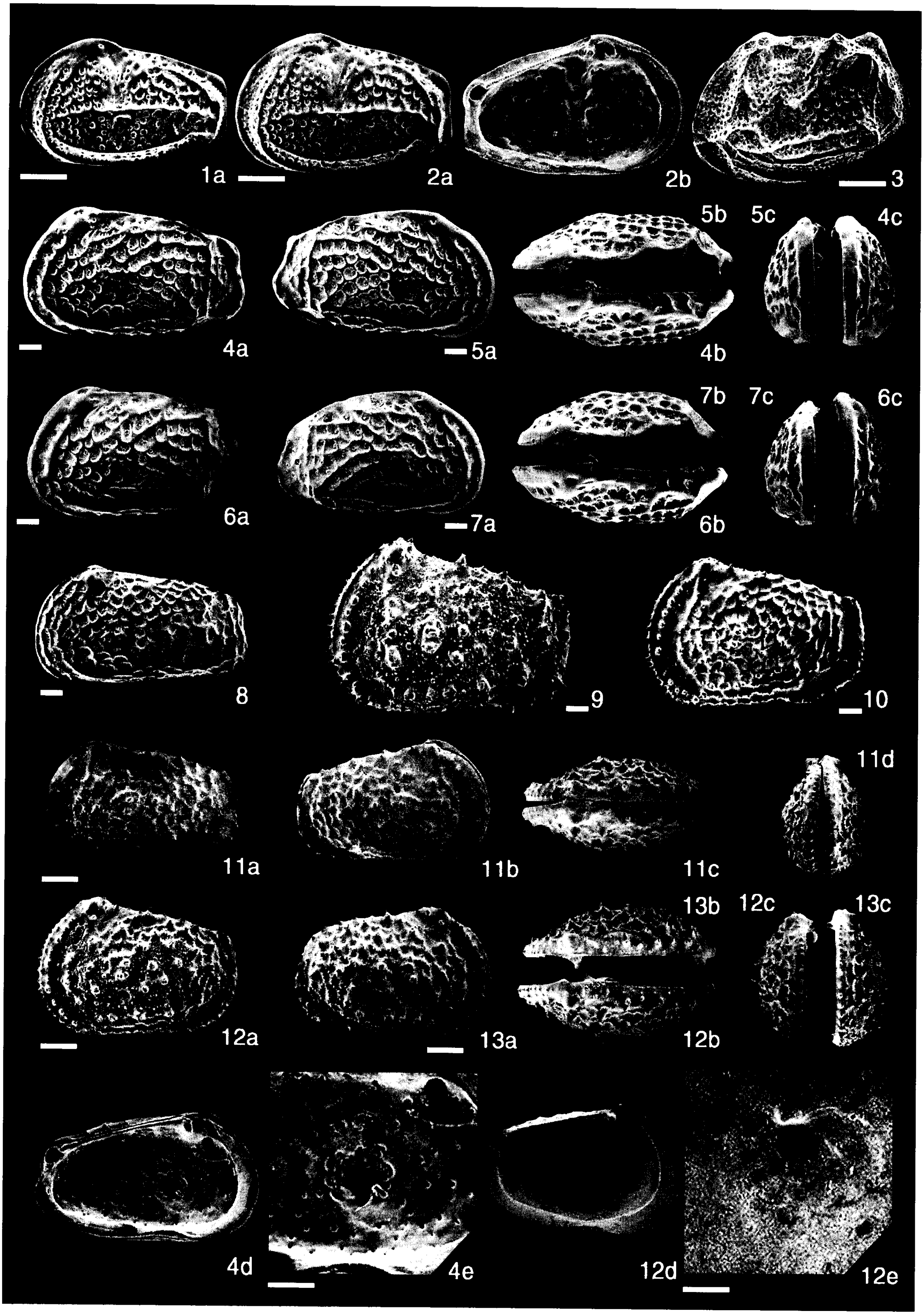
Cythere limicola Norman, 1865a, p. 193; Norman, 1865b, p. 20, pl. 6, figs. 1-4.

Palmenella limicola (Norman). Hirschmann, 1916, p. 582-594, text-figs.8-27; Elofson, 1941, p.277, 278, text-fig. 21; Triebel, 1949, p.189, 190, pl. 2, figs. 5, 6; Swain, 1963, p.830, 831, pl.99, figs. 3a-d, text-fig.9d; Ishizaki, 1966, p.156, pl.19, fig. 8; Hanai, 1970, p. 704, text-figs. 6B (solid line), 7G, H; Neale and Howe, 1975, pl. 5, figs. 7, 8; Rosenfeld, 1977, p. 15, 16, pl. 1, figs. 3-6; Lord, 1980, pl. 3, fig. 6; Cronin, 1981, p. 412, pl. 11, figs. 1, 2, 4; Cheong *et al.*, 1986, pl. 2, fig. 1; McDougall *et al.*, 1986, pl. 13, fig. 8; Cronin and Ikeya, 1987, p. 86, pl. 2, fig. 17; Brouwers, 1988, figs. 5, 6; Yajima, 1988, pl. 2, fig. 8; Athersuch *et al.*, 1989, p. 82, 83, pl. 1 (2), fig. 28; Brouwers, 1990, pl. 1, fig. 15, pl. 4, figs. 9, 12, 17, pl. 6, fig. 1; Brouwers *et al.*, 1991, pl. 1, fig. 7; Cronin, 1991, fig. 7-11; Huh and Paik, 1992a, pl. 1, fig. 10; Huh and Paik, 1992b, pl. 1, fig. 10; Hartmann, 1993, p.241, pl. 1, figs. 2-4; Irizuki, 1994, p. 8, pl. 1, fig. 4; Irizuki and Matsubara, 1994, pl. 1, fig. 7; Ozawa *et al.*, 1995, pl. 1, fig. 4; Kamiya *et al.*, 1996, pl. 2, fig. 1; Ozawa, 1996, pl. 7, fig. 9; Irizuki *et al.*, 1998, fig. 5-8; Freiwald and Mostafawi, 1998, pl. 59, fig. 4; (not) Wagner, 1970, pl. 4, fig. 14.

Kyphocythere limnicola (Norman). Swain, 1961, fig. 2-20.

Palmenella sp. Hanai, 1961, p. 369, text-fig.11, figs. 4a, b.

Occurrences.—Miocene to Recent sediments of high-latitude areas (N1, P1a, b, Q1a, b, R2a-e, P3, R3a, c, Q4a, b, M5a, b, P5a, b, H6a, R6a, b, R7a, b, R8, M9b-f, P9d, Q9, R9c; see Figure 4).


1a
2a
2b
3
5b
5c
4c
4a
5a
4b
7b
7c
6c
6a
7a
6b
8
9
10
11d
11a
11b
11c
13b
12c
13c
12a
13a
12b
4d
4e
12d
12e

Family Hemicytheridae Puri, 1953
Subfamily Urocythereidinae Hartmann and Puri, 1974
Genus ***Urocythereis*** Ruggieri, 1950

Urocythereis pohangensis Huh and Whatley, 1997

Figure 7.8

Urocythereis pohangensis Huh and Whatley, 1997, p. 36, 37, pl. 2, figs. 3–9.

Urocythereis sp. Huh and Paik, 1992a, pl. 1, figs. 17, 18; Huh and Paik, 1992b, pl. 1, figs. 17, 18.

Remarks.—This is the first report of *U. pohangensis* from Japan.

Occurrences.—Miocene sediments of the south Japan Sea side areas (M9d,e; see Figure 4).

Genus ***Laperousecythere*** Brouwers, 1993

Laperousecythere ikeyai Tanaka sp. nov.

Figures 5.4, 7.4–7.7

Etymology.—In honor of N. Ikeya (Shizuoka University, Japan), who is a specialist in the taxonomy and biogeography of the Cenozoic and Recent marine ostracods of the western Pacific region.

Types.—Holotype, LV of male, SUM-CO-1225(L = 0.95 mm, H = 0.51 mm). Paratypes, RV of male, SUM-CO-1226 (L = 0.95 mm, H = 0.49 mm); LV of female, SUM-CO-227 (L = 0.92 mm, H = 0.55 mm); RV of female, SUM-CO-1228 (L = 0.89 mm, H = 0.49 mm); LV of male, SUM-CO-1229 (L = 0.91 mm, H = 0.52 mm).

Type locality.—Loc. 1-A15.

Diagnosis.—Valve subquadrate. Surface ornamented by polygonal reticulations and a carinal ridge runs nearly parallel to anterior and ventral margin. Vestibule narrow. Four circular/elliptical adductor scars, in three of these the ventral side is subdivided.

Description.—Valve subquadrate in lateral view. Anterior margin evenly rounded with infracurvature; dorsal margin straight, sloping gently toward posterior; posterior margin truncated and caudated ventrally; ventral margin nearly straight to slightly convex. Large sexual dimorphism; in lateral view, male forms more elongate; in dorsal view, the carapaces of female forms are inflated posteroventrally. Eye spot large and flat. Surface ornamented by polygonal reticulations. A strong carinal ridge occurs at base of eye spot, runs nearly parallel to anterior and ventral margin, and ends at posteroventral area. A subcentral tubercle is developed. In dorsal view, lateral outline nearly straight; anterior end more pointed than posterior. On dorsal surface of carapace a V-shaped groove runs along hinge line (in vertical section). In anterior view, carapace subovate, broadest at point near mid-height. Marginal zone relatively broad, with narrow anterior and posterior vestibula. Marginal pore canals are straight and number 35 in anterior, 17 in posterior, and a few mid-ventrally. Selvage and list well developed. Hinge holamphidont: in LV, anterior element has an auxiliary tooth in a large elongate socket; anteromedian element is a smooth tooth, posteromedian element is a bar; posterior element is an elongate socket. Three frontal scars (the upper two are circular, the lowermost one is elliptical). Four circular/elliptical adductor scars; the three at ventral side are subdivided. A deep anteromedian depression between frontal and adductor scars, corresponding to the external subcentral tubercle. One elliptical mandibular scar. Six dorsal scars (two dorsomedially; two mid-dorsally; two anterodorsally); the uppermost one is semicircular, the others are circular/elliptical. Prominent fulcral point. One semicircular ventral scar is below and anterior to the mandibular scar. Ocular sinus conspicuous. *Remarks.*—This species differs from *L. robusta* (Tabuki, 1986) from the Plio-Pleistocene Daishaka Formation, northern Japan, in its slightly convexed ventral margin, polygonal reticulation and lack of secondary reticulations. The present species is distinguished from *L. ishizakii* Irizuki and Matsubara, 1995 from the Early-Middle Miocene Suenomatsuyama Formation, northeast Japan, in its outline and possession of a strong carinal ridge.

Occurrence.—Only from the Fujina Formation (M9e; see Figure 4).

Family Trachyleberididae Sylvester-Bradley, 1948
Subfamily Trachyleberidinae Sylvester-Bradley, 1948
Tribe Trachyleberidini Sylvester-Bradley, 1948
Genus ***Acanthocythereis*** Howe, 1963

← **Figure 7.** **1–2**, *Paijenborchella* cf. *tsurugasakensis* Tabuki, 1986. **1a**: male LV, Loc. 1–A17, SUM-CO–1221; **2a, b**: female LV, Loc. 1–A16, SUM-CO–1222; **3**: *Palmenella limicola* (Norman, 1865), female LV, Loc. 1–A18, SUM-CO–1223. **4–7**, *Laperousecythere ikeyai* Tanaka sp. nov. **4a–e**: male LV, holotype, Loc. 1–A15, SUM-CO–1225; **5a–c**: male RV, paratype, Loc. 1–A15, SUM-CO–1226; **6a–c**: female LV, paratype, Loc. 1–A15, SUM-CO–1227; **7a–c**: female RV, paratype, Loc. 1–A15, SUM-CO–1228. **8**: *Urocythereis pohangensis* Huh and Whatley, 1997, male LV, Loc. 1–A15, SUM-CO–1224. **9**: *Acanthocythereis dunelmensis* (Norman, 1865), female LV, Loc. 2–B4, SUM-CO–1230. **10**: *Acanthocythereis koreana* Huh and Whatley, 1997, female LV, Loc. 1–A13, SUM-CO–1240. **11–13**, *Acanthocythereis fujinaensis* Tanaka sp. nov. **11a–d**: male C, holotype, Loc. 1–A13, SUM-CO–1231; **12a–e**: female LV, paratype, Loc. 1–A11, SUM-CO–1232; **13a–c**: female RV, paratype, Loc. 1–A11, SUM-CO–1233. Scale bar is 0.10 mm.

Acanthocythereis dunelmensis (Norman, 1865)

Figure 7.9

Cythereis dunelmensis Norman, 1865a, p. 193; Norman, 1865b, p. 22, pl. 7, figs. 1-4.
Cythere dunelmensis (Norman). Brady, 1868, p. 416, pl. 30, figs. 1-12.
Cythereis dunelmensis (Norman). Elofson, 1941, p. 296-300, figs. 8-11, text-figs. 29, 30; Elofson, 1943, p. 10; (not) Tressler, 1941, p. 100, pl. 19, fig. 21.
Trachyleberis dunelmensis (Norman). Hulings, 1967, p. 324, figs. 7, 8T, pl.4, figs. 24, 25; Caralp *et al.*, 1967, pl.13, fig. 1; Caralp *et al.*, 1968, pl.10, fig. 1.
Acanthocythereis dunelmensis (Norman). Neale and Howe, 1975, pl. 1, figs. 3, 11, 13-16; Rosenfeld, 1977, p. 23, 24, pl. 5, figs. 65-68; Lord, 1980, pl. 1, figs. 8-13; Cronin, 1981, p. 400, pl. 8, figs. 1, 2; Cronin, 1986, pl. 2, fig. 9; McDougall *et al.*, 1986, pl. 13, figs. 2-4; Cronin and Ikeya, 1987, pl. 1, figs. 1, 4; Brouwers, 1988, figs. 5-7; Athersuch *et al.*, 1989, p. 133, 134, pl. 3 (10), fig. 52; Cronin, 1989, pl. 2, fig. 9; McKenzie *et al.*, 1989, pl. 1, fig. 1; Hartmann, 1992, pl. 5, figs.4-6; Ikeya and Suzuki, 1992, pl. 1, fig. 2; Brouwers, 1993, pl. 1, figs. 1-5, pl. 2, fig. 1, pl. 16, fig. 1, text-fig. 3, 4; Irizuki, 1994, p. 10, pl. 2, fig. 3; Irizuki, 1996, figs. 7-1, 2; Kamiya *et al.*, 1996, pl. 2, figs. 8-10; Ozawa, 1996, pl. 1, fig. 1; Freiwald and Mostafawi, 1998, pl. 59, figs. 1, 2.
Acanthocythereis cf. *A. dunelmensis* (Norman). Penney, 1993, fig. 5-I.
? *Acanthocythereis dunelmensis* (Norman). Cronin and Compton-Gooding, 1987, pl. 2, fig. 4.
? *Acanthocythereis* cf. *A. dunelmensis* (Norman). Cronin, 1991, fig. 8-11.
Cletocythereis dunelmensis dunelmensis (Norman). Bassiouni, 1965, pl. 2, fig. 8.
Cletocythereis dunelmensis minor Bassiouni, 1965, p. 513, 514, pl. 2, fig. 9.
Actinocythereis sp., Swain, 1961, fig. 2-36.
Cletocythereis elofsoni elofsoni Bassiouni, 1965, p. 514-516, pl. 2, figs. 4, 5.
Cletocythereis elofsoni elofsoni abbreviata, Bassiouni, 1965, p. 516, pl. 2, figs. 6, 7.
Cletocythereis noblissimus Swain, 1963, p. 824, 825, pl. 98, fig. 5, pl. 99, figs. 15a, b, text-fig. 10a.
Acanthocythereis ? sp. A Cheong *et al.*, 1986, pl. 2, fig. 17.
Acanthocythereis ? sp. B Cheong *et al.*, 1986, pl. 2, fig. 18.
Acanthocythereis ? sp. C Cheong *et al.*, 1986, pl. 2, fig. 19.
Trachyleberis ? *rastromarginata* (Brady). Swain, 1961, fig. 2-32.

Occurrences.—Miocene to Recent sediments of high-latitude areas (R2a-f, P3, R3a, b, d, Q4a-c, P5a, b, Q5a, b, Q6a, H6a, R6a, b, Q7a-e, R7a-d, R8, M9b, N9b, P9a, b, d, R9b, c; see Figure 4).

Acanthocythereis fujinaensis Tanaka sp. nov.

Figures 5.5, 7.11-7.13

Etymology.—For the type locality.

Types.—Holotype, C of male, SUM-CO-1231 (L = 0.41 mm, H = 0.24 mm). Paratypes, LV of female, SUM-CO-1232 (L = 0.43 mm, H = 0.27 mm); RV of female, SUM-CO-1233 (L = 0.42 mm, H = 0.27 mm); LV of female, SUM-CO-1234 (L = 0.46 mm, H = 0.29 mm).

Type locality.—Loc. 1-A13.

Diagnosis.—Valve subquadrate. Posterior margin evenly rounded. Conical spines developed in the anteroventral margin. Surface ornamented by polygonal reticulations with clavate/conic conjunctive spines.

Description.—Valve subquadrate in lateral view. Anterior margin evenly rounded with conical spines, especially anteroventrally; dorsal margin straight, sloping toward posterior with several spines; posterior margin evenly rounded with conical spines posteroventrally; ventral margin concave in male forms, nearly straight in female forms. Strong sexual dimorphism; in lateral view, male forms more elongate; in dorsal view, carapaces of female forms inflated posteroventrally. Eye spot large and protruding. Surface ornamented by polygonal reticulations with clavate/conical conjunctive spines. A row of clavate/conical spines occurs at base of eye spot, runs parallel to anterior margin. Three parallel carinal ridges occupy the midventral area, the uppermost one with clavate spines. A subcentral tubercle developed. In dorsal view, carapace elongate subovate, pointed in front. In anterior view, carapace subovate, lateral outline nearly straight. Marginal zone relatively broad, with very narrow anterior and posterior vestibula. Marginal pore canals are straight/curved with median swellings and number 42 in anterior, 18 in ventral, 23 in posterior. Selvage developed. Hinge holamphidont: in LV, anterior element has an auxiliary tooth in a large elongate socket; anteromedian element is a smooth tooth, posteromedian element is a bar; posterior element is an elongate socket. One U-shaped frontal scar. Four adductor scars in a vertical row (the uppermost one is semicircular, the lower three are elliptical). One elliptical mandibular scar. Three dorsal scars mid-dorsally; the lowermost one protrudes like a tongue, the upper two are elliptical. Prominent fulcral point. One elliptical ventral scar is below and anterior to the mandibular scar. Ocular sinus conspicuous.

Remarks.—This species differs from *A. koreana* Huh and Whatley, 1997 from the Miocene, Korea, in its evenly rounded posterior margin, developed anteroventral conical spines and prominent clavate conjunctive spines.

Occurrence.—Only from the Fujina Formation (M9e; see Figure 4).

Acanthocythereis izumoensis Tanaka sp. nov.

Figures 5.6, 8.1–8.4

Etymology.—Izumo is the ancient provincial name of the type locality.

Types.—Holotype, LV of male, SUM-CO-1235 (L = 0.92 mm, H = 0.56 mm). Paratypes, RV of male, SUM-CO-1236 (L = 0.91 mm, H = 0.53 mm); LV of female, SUM-CO-1237 (L = 0.90 mm, H = 0.60 mm); RV of female, SUM-CO-1238 (L = 0.92 mm, H = 0.59 mm); LV of female, SUM-CO-1239 (L = 0.90mm, H = 0.61 mm).

Type locality.—Loc. 1-A16.

Diagnosis.—Valve subquadrate. In male forms, a large conical spine at the posteroventral corner is prominent. Surface smooth with scattered clavate/conical spines. A row of clavate spines runs parallel to mid-ventral margin. In anterior view, carapace subtrapezoidal, broadest at about one-fifth height from the ventral side. No vestibule.

Description. — Valve subquadrate in lateral view. Anterior margin evenly rounded with conical spines, especially anteroventrally; dorsal margin straight, sloping toward posterior with several clavate/conical spines; posterior margin evenly rounded with several conical spines, a large conical spine at the posteroventral corner is more prominent in male forms; ventral margin convex. Strong sexual dimorphism; in lateral view, male forms more elongate; in dorsal view, female forms having inflated carapace in the mid-posterior area. Eye spot large and protruding. Surface smooth with scattered clavate/conical spines. A row of clavate/conical spines occurs at base of the eye spot, runs parallel to anterior margin. A row of clavate spines runs parallel to mid-ventral margin. In dorsal view, carapace elongate subovate, pointed in front. In anterior view, carapace subtrapezoidal, broadest at about one-fifth height from the ventral side. Marginal zone broad; vestibule not developed. Marginal pore canals are straight/curved with median swellings and number 40 in anterior and 20 in posterior. Selvage developed. Hinge holamphidont: in LV, anterior element has an auxiliary tooth in a large elongate socket; anteromedian element is a smooth tooth, posteromedian element is a bar; posterior element is an elongate socket. One V-shaped frontal scar. Four adductor scars in a vertical row (the uppermost and lowermost are semicircular, the middle two are elliptical). One elliptical mandibular scar. Three dorsal scars; the dorsomedian one protrudes like a tongue, the mid-dorsal two are elongate. Prominent fulcral point. One elliptical ventral scar is below and posterior to the mandibular scar. Ocular sinus conspicuous.

Remarks. — This species differs from *A. mutsuensis* Ishizaki, 1971 from the Recent sediments of Mutsu Bay in northern Japan, in its row of clavate spines running parallel to the mid-ventral margin. The present species is distinguished from *A. koreana* Huh and Whatley, 1997 from the Miocene, Korea, by its smooth surface with scattered clavate/conical spines.

Occurrence. — Only from the Fujina Formation (M9e; see Figure 4).

Acanthocythereis koreana Huh and Whatley, 1997

Figure 7.10

Acanthocythereis koreana Huh and Whatley, 1997, p. 39, pl. 3, figs. 6–12.

Acanthocythereis mutsuensis Ishizaki. Huh and Paik, 1992a, pl. 2, figs. 8, 9; Huh and Paik, 1992b, pl. 2, figs. 8, 9.

Acanthocythereis dunelmensis (Norman). Irizuki and Matsubara, 1994, pl. 1, fig. 13.

Occurrences. — Miocene sediments of the south Japan Sea side areas (M9d, e; see Figure 4).

Acanthocythereis tsurugasakensis Tabuki, 1986

Figure 8.5

Acanthocythereis tsurugasakensis Tabuki, 1986, p. 85, 86, pl. 11, figs. 2–10, text-fig. 20–2; Ozawa, 1996, pl. 1, fig. 3.

Occurrences.—Miocene to Pleistocene sediments along the Japan Sea and Northern Pacific areas of Japan (P5c, M9e and P9d; see Figure 4).

Genus ***Robertsonites*** Swain, 1963

Robertsonites japonicus (Ishizaki, 1966)

Figure 8.6

Buntonia japonica Ishizaki, 1966, p. 156, 157, pl. 19, figs. 6, 7, text-fig.1, figs. 1, 5.

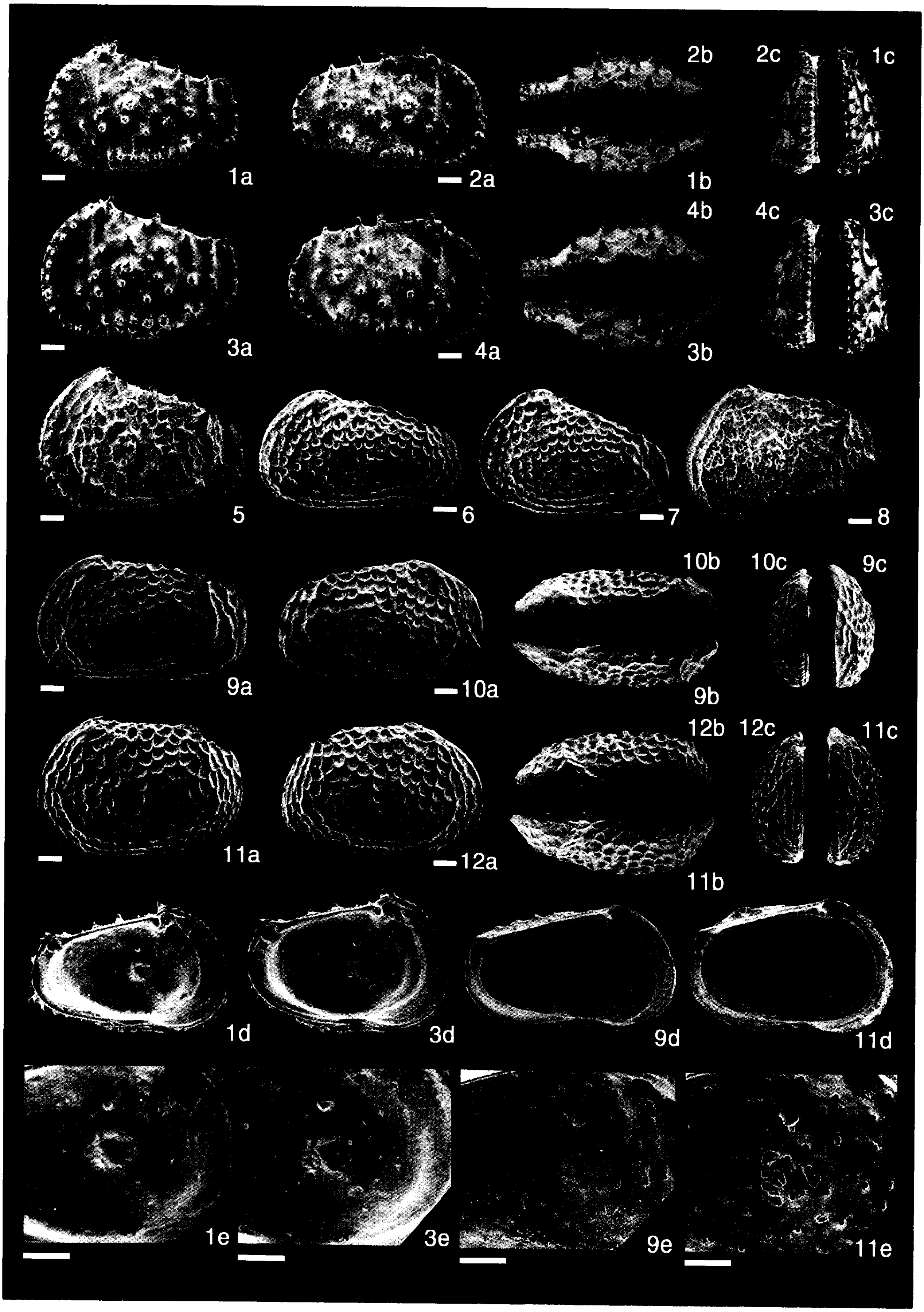
Occurrences. — Miocene sediments of Honshu, Japan (M9a, e; see Figure 4).

Robertsonites reticuliformus (Ishizaki, 1966)

Figure 8.7

Buntonia reticuliforma Ishizaki, 1966, p. 157, 158, pl. 16, fig. 7, text-fig.1, fig. 1; Tabuki, 1986, p. 91–93, pl. 14, figs. 1–12, text-figs. 17–1, 2; Cronin and Ikeya, 1987, p. 84, pl. 2, fig. 15; Yajima and Lord, 1990, fig. 4–9; Huh and Paik, 1992a, b, pl. 2, fig. 13; Irizuki, 1994, p. 10, pl. 2, figs. 4–6; Irizuki, 1996, figs. 7–3, 4; Kamiya *et al.*, 1996, pl. 3, fig. 6; Ozawa, 1996, pl. 8, fig. 6.

Robertsonites ? *reticuliforma* (Ishizaki) [*sic*]. Yajima, 1982, p. 205, pl. 12, fig. 13.


1a
2a
2b
1b
2c
1c
3a
4a
4b
3b
4c
3c
5
6
7
8
9a
10a
10b
9b
10c
9c
11a
12a
12b
11b
12c
11c
1d
3d
9d
11d
1e
3e
9e
11e

Remarks.—This species was first described by Ishizaki (1966) from the Middle Miocene Hatatate Formation in northern Japan. Specimens in Tabuki (1986), Irizuki (1994, 1996), Kamiya *et al.* (1996) and Ozawa (1996) have a prominent posterodorsal subvertical ridge.

Occurrences. — Miocene to Pleistocene sediments of Honshu, Japan (P5c, Q5a, b, M9a, b, d, N9b, P9a, c, d, Q9a; see Figure 4).

Robertsonites cf. ***tuberculatus*** (Sars, 1866)

Figure 8.8

Cythereis tuberculata Sars, 1866, p. 37.

Cythere tuberculata (Sars). Brady, 1868, p. 406, 407, pl. 30, figs. 25-39.

Robertsonites tuberculata (Sars) [*sic*]. Hulings, 1967, p. 324, pl. 4, figs. 21-23; text-figs. 4e, 8p-8s; Neale and Howe, 1975, p. 419, pl. 1, fig. 1; Rosenfeld, 1977, p. 24, 25, pl. 5, figs. 61-64.

Robertsonites tuberculatus (Sars). Cronin, 1981, p. 400, 402, pl. 8, fig. 5; Horne, 1983, p. 39-52, pls. 1-14; Athersuch *et al.*, 1989, p. 148, 149, pl. 4 (7), fig. 59; Cronin, 1989, p. 133, pl. 2, fig. 10; McKenzie *et al.*, 1989, pl. 1, fig. 12; Cronin, 1991, p. 779, fig. 8-2; Hartmann, 1992, p. 187, 188, pl. 5, figs. 7-12; pl. 6, figs. 1-6; Penney, 1993, fig. 5h.

Robertsonites gubikensis Swain, 1963, p. 821, 822, pl. 98, figs. 8a, b; pl. 99, fig. 12; text-fig. 9b.

Robertsonites logani (Brady and Crosskey). Swain, 1963, p. 823, pl. 97, fig. 13.

Robertsonites tuberculatina [*sic*] Swain, 1963, p. 822, 823, pl. 98, fig. 10; pl. 99, fig. 1; text-fig. 9c.

Remarks.—This species exhibits considerable variation in outline and ornament, with variable development of nodes and reticulation (Brouwers, 1993).

Occurrences.—Miocene to Recent sediments of high-latitude areas (N1, R2b, f, N3, P3, R3d, Q4b, c, R6a, b, Q7b-e, R7c; see Figure 4).

Robertsonites yatsukanus Tanaka sp. nov.

Figures 5.7, 8.9-8.12

Etymology.—The district name of the type locality.

Types.—Holotype, LV of male, SUM-CO-1245 (L = 0.95 mm, H = 0.53 mm). Paratypes, RV of male, SUM-CO-1246 (L = 0.93 mm, H = 0.51 mm); LV of female, SUM-CO-1247 (L = 0.94 mm, H = 0.59 mm); RV of female, SUM-CO-1248 (L = 0.91 mm, H = 0.55 mm); LV of male, SUM-CO-1249 (L = 0.94 mm, H = 0.54 mm).

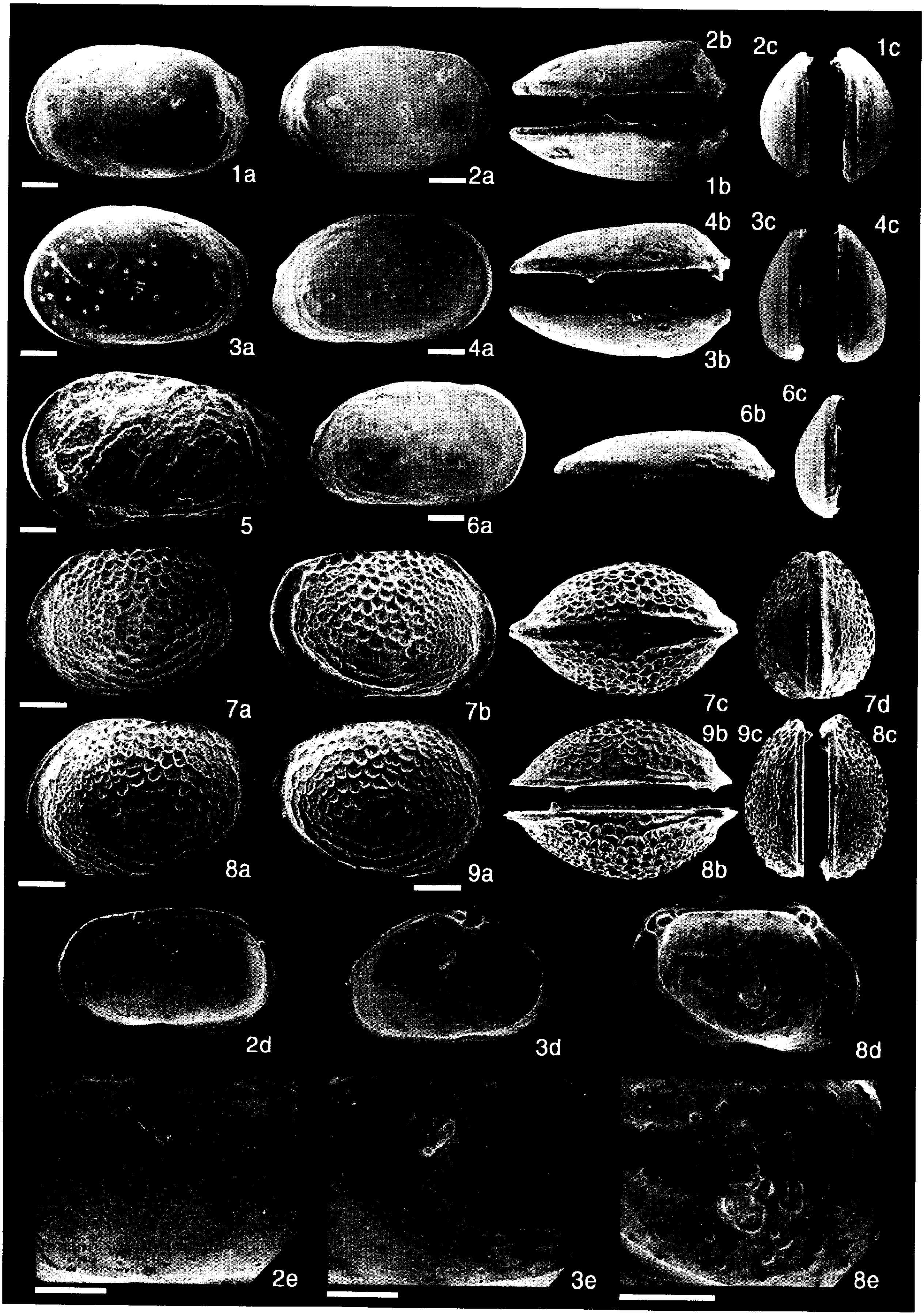
Type locality.—Loc. 2-B1.

Diagnosis.—Valve quadrate, tapering posteriorly. Surface ornamented by polygonal reticulations. Vestibula developed in the anteroventral area and very narrow in the posteroventral area. One J-shaped frontal scar.

Description. — Valve quadrate, tapering posteriorly in lateral view. Anterior margin evenly rounded, weakly denticulated anteroventrally; dorsal margin undulate, sloping toward posterior; posterior margin evenly rounded and weakly denticulated anteroventrally; ventral margin nearly straight. Strong sexual dimorphism; in lateral view, male forms are more elongate; in dorsal view female carapaces are inflated posteriorly. Eye spot small and flat. Surface ornamented by polygonal reticulations. Two anterior carinal ridges prominent, one running from the anterior part of eye spot to the anteroventral area, the other starting at base of eye spot, bifurcating in anterodorsal area and running into anteroventral area. Three carinal ridges run nearly parallel to anterior, ventral and posterior margin and end at posterodorsal area. In dorsal view, carapace is elongate ovate. In dorsal surface of carapace a V-shaped groove runs along hinge line (in a vertical section). In anterior view, carapace subovate, broadest at point near mid-height. Marginal zone relatively broad, vestibula developed in the anteroventral area and very narrow in the posteroventral area. Marginal pore canals straight, number 48 anteriorly, 15 ventrally and 14 posteriorly. Selvage developed. Hinge holamphidont: in LV, anterior element is a large elongate socket; anteromedian element is a tongue like tooth, posteromedian element is a bar; posterior element is an elongate socket. One J-shaped frontal scar. Four adductor scars in a vertical row (the uppermost and lowermost are semicircular, the middle two are narrow). One elliptical mandibular scar. Eight dorsal scars (five dorsomedially; two mid-dorsally; one anterodorsally); the dorsomedian one protrude like a tongue, the others are circular/elliptical. Fulcral point not observed. One elliptical ventral scar is below and posterior to the mandibular scar. Ocular sinus conspicuous.

Remarks.—This species differs from *R. hanaii* Tabuki, 1986 from the Plio-Pleistocene Daishaka Formation in

← **Figure 8.** **1-4**, *Acanthocythereis izumoensis* Tanaka sp. nov. **1a-e**: male LV, holotype, Loc. 1-A16, SUM-CO-1235; **2a-e**: male RV, paratype, Loc. 1-A16, SUM-CO-1236; **3a-c**: female LV, paratype, Loc. 1-A16, SUM-CO-1237; **4a-c**: female RV, paratype, Loc. 1-A17, SUM-CO-1238. **5**: *Acanthocythereis tsurugasakensis* Tabuki, 1986, female LV, Loc. 2-B2, SUM-CO-1241. **6**: *Robertsonites japonicus* (Ishizaki, 1966), male LV, Loc. 1-A11, SUM-CO-1242. **7**: *Robertsonites reticuliformus* (Ishizaki, 1966), male LV, Loc. 1-A15, SUM-CO-1243. **8**: *Robertsonites* cf. *tuberculatus* (Sars, 1866), female LV, Loc. 2-B4, SUM-CO-1244. **9-12**, *Robertsonites yatsukanus* Tanaka sp. nov. **9a-e**: male LV, holotype, Loc. 2-B1, SUM-CO-1245; **10a-c**: male RV, paratype, Loc. 2-B1, SUM-CO-1246; **11a-e**: female LV, paratype, Loc. 2-B1, SUM-CO-1247; **12a-c**: female RV, paratype, Loc. 2-B1, SUM-CO-1248. Scale bar is 0.10 mm.


1a
2a
2b
2c
1c
1b
3a
4a
4b
3c
4c
3b
5
6a
6b
6c
7a
7b
7c
7d
8a
9a
9b
9c
8c
8b
2d
3d
8d
2e
3e
8e

northern Japan, in its inflated carapace and three carinal ridges running nearly parallel to anterior, ventral and posterior margins. *R. yatsukanus* is distinguished from *R. tsugaruana* [*sic*] Tabuki, 1986 from the Plio-Pleistocene Daishaka Formation in northern Japan, in lack of secondary reticulations.

Occurrence.—Only from the Fujina Formation (M9e; see Figure 4).

Subfamily Buntoniinae Apostolescu, 1961
Genus ***Ambtonia*** Malz, 1982

Ambtonia shimanensis Tanaka sp. nov.

Figures 5.8, 9.1, 9.2

Etymology.—The prefecture name, Shimane, of the type locality.

Types.—Holotype, RV, SUM-CO-1250 (L = 0.61 mm, H = 0.33 mm). Paratypes, LV, SUM-CO-1251 (L = 0.63 mm, H = 0.35 mm); LV, SUM-CO-1252 (L = 0.65 mm, H = 0.36 mm).

Type locality.—Loc. 1-A11.

Diagnosis. — Valve subcylindrical. Dorsal margin nearly straight. In dorsal view, carapace elongately arrowhead-shaped, tapered in front. Maximum width about one-sixth length from the posterior end. In anterior view, carapace subovate, broadest near mid-height. One V-shaped frontal scar.

Description. — Valve subcylindrical in lateral view. Anterior margin evenly rounded; dorsal margin nearly straight; truncated and caudate ventrally; ventral margin nearly straight to slightly convex. Sexual dimorphism unknown. Eye spot not observed. Surface smooth, scattered deep punctations which are the openings of normal pore canals. Anterior area compressed along the anterior margin. In dorsal view, carapace elongately arrowhead-shaped, tapered in front. Maximum width at about one-sixth length from the posterior end. In anterior view, carapace subovate, broadest at point near mid-height. Marginal zone broad in the anterior area, vestibula developed in the anteroventral area and very narrow in the posteroventral area. Marginal pore canals are straight and number 39 anteriorly, 7 ventrally and 11 posteriorly. Selvage and list well developed. Hinge hemiamphidont: in LV, anterior element has a large elongate socket; anteromedian element is a smooth elongate tooth, posteromedian element is a crenulate bar; posterior element is an elongate socket with several lobes dorsally. One V-shaped frontal scar. Four elliptical adductor scars in a vertical row, the middle two of which are narrow. One elliptical mandibular scar. Two dorsal scars protrude like pivots in the dorsomedian area. Fulcral point not observed. One small round ventral scar is below and posterior to the mandibular scar. No ocular sinus.

Remarks.—This species differs from *A. obai* (Ishizaki, 1971) from the Recent sediments of Mutsu Bay in northern Japan, in its caudate posteroventral margin, slightly convex ventral margin and compressed anterior area. The present species is distinguished from *A. tongassensis* Brouwers, 1993 from the Quaternary sediments of the Gulf of Alaska, North America, in its caudated posteroventral margin, nearly parallel dorsal and ventral margins, and number of marginal pore canals. This species differs from *A. glabra* Malz, 1982 from the Plio-Pleistocene Ssukou Formation of southwest Taiwan, in its straight dorsal margin.

Occurrence.—Only from the Fujina Formation (M9e; see Figure 4).

Ambtonia takayasui Tanaka sp. nov.

Figures 5.9, 9.3, 9.4, 9.6

Falsobuntonia taiwanica Malz. Yajima, 1988, pl. 1, fig. 7; Huh and Paik, 1992b, pl. 2, fig. 14.
Ambtonia obai (Ishizaki). Huh and Paik, 1992a, pl. 2, fig. 14.

Etymology.—In honor of K. Takayasu (Center for Coastal Lagoon Environments of Shimane University, Japan), who is a specialist in the taxonomy and paleoecology of the molluscs of the Fujina Formation.

Types.—Holotype, LV of female, SUM-CO-1253 (L = 0.64 mm, H = 0.37 mm). Paratypes, RV of female, SUM-CO-1254 (L = 0.63 mm, H = 0.33 mm); RV of male, SUM-CO-1255 (L = 0.62 mm, H = 0.33 mm); LV of female, SUM-CO-1256 (L = 0.64 mm, H = 0.37 mm).

Type locality.—Loc. 1-A16.

Diagnosis. — Valve subcylindrical. Dorsal margin arched. In dorsal view, carapace elongately arrowhead-shaped, tapered in front. Maximum width about one-fifth length from the posterior end. In anterior view, carapace subpentagonal, lateral outline nearly straight. One J-shaped frontal scar.

Description. — Valve subcylindrical in lateral view. Anterior margin evenly rounded; dorsal margin arched; posterior margin truncated and caudated ventrally; ventral

← **Figure 9.** **1–2**, *Ambtonia shimanensis* Tanaka sp. nov. **1a–c**: LV, paratype, Loc. 1-A11, SUM-CO-1251; **2a–e**: RV, holotype, Loc. 1-A11, SUM-CO-1250. **3–4, 6**, *Ambtonia takayasui* Tanaka sp. nov. **3a–e**: female LV, holotype, Loc. 1-A16, SUM-CO-1253; **4a–c**: female RV, paratype, Loc. 1-A16, SUM-CO-1254; **6a–c**: male RV, paratype, Loc. 1-A11, SUM-CO-1255. **5**: *Falsobuntonia taiwanica* Malz, 1982, male LV, Loc. 1-A20, SUM-CO-1257. **7–9**, *Palmoconcha irizukii* Tanaka sp. nov. **7a–d**: male C, holotype, Loc. 1-A15, SUM-CO-1258; **8a–e**: female LV, paratype, Loc. 1-A15, SUM-CO-1259; 9a–c: female RV, paratype, Loc. 1-A15, SUM-CO-1260. Scale bar is 0.10 mm.

margin straight. Weak sexual dimorphism. Eye spot not observed. Surface smooth; scattered deep punctations, which are the openings of normal pore canals. Anterior area compressed along the anterior margin. Three weak muri run parallel to posterior margin in the posterior area. In dorsal view, carapace elongately arrowhead-shaped, tapered in front. Maximum width about one-fifth length from the posterior end. In anterior view, carapace subpentagonal, lateral outline nearly straight. Marginal zone broad in the anterior area, vestibula developed in the anteroventral area and very narrow in the posteroventral area. Marginal pore canals straight, number 39 anteriorly, 6 ventrally and 15 posteriorly. Selvage and list well developed. Hinge hemiamphidont: in LV, anterior element has a large elongate socket; anteromedian element is a smooth elongate tooth, posteromedian element is a crenulate bar; posterior element is an elongate socket with several lobes dorsally. One J-shaped frontal scar. Four elliptical adductor scars in a vertical row, the middle two are narrow. One round mandibular scar. Two dorsal scars protrude like pivots in the dorsomedian area. Fulcral point not observed. One small round ventral scar is below and posterior to the mandibular scar. No ocular sinus.

Remarks.—This species differs from *A. tongassensis* Brouwers, 1993 from the Quaternary sediments of the Gulf of Alaska, North America, in its outline in lateral view.

Occurrence.—Miocene formations from Japan and Korea (M9d, e, g; see Figure 4).

Falsobuntonia taiwanica Malz, 1982

Figure 9.5

Falsobuntonia taiwanica Malz, 1982, p. 392, 393, pl. 8, figs. 51-56; Huh and Paik, 1992a, pl. 2, fig. 15; Huh and Paik, 1992b, p. 111, pl. 2, fig 15; (non) Yajima, 1988, pl. 1, fig. 7; Huh and Paik, 1992b, p. 111, pl. 2, fig. 14.

Occurrences.—Miocene to Pleistocene sediments of Japan, Korea and Taiwan (M9d, e and P9e; see Figure 4).

Family Loxoconchidae Sars, 1926
Genus ***Palmoconcha*** Swain and Gilby, 1974

Palmoconcha irizukii Tanaka sp. nov.

Figures 5.10, 9.7-9.9

Palmoconcha sp. Irizuki and Matsubara, 1994, pl. 1, fig. 19.

Etymology.—In honor of T. Irizuki (Aichi University of Education, Japan) who is a specialist in the study of Cenozoic fossil ostracod assemblages of Japan. *Types.*—Holotype, C of male, SUM-CO-1258 (L = 0.47 mm, H = 0.28 mm). Paratypes, LV of female, SUM-CO-1259 (L = 0.49 mm, H = 0.31 mm); RV of female, SUM-CO-1260 (L = 0.46 mm, H = 0.31 mm); LV of female, SUM-CO-1261 (L = 0.51 mm, H = 0.34 mm).

Type locality.—Loc. 1-A15.

Diagnosis.—Valve rhomboidal. Surface ornamented by punctations in the anterior area. Three concentric muri occur in the anteroventral area, convex ventrally in the mid-ventral area, ends in mid-posterior area. One prominent murus runs from the mid-dorsal area to the posterodorsal area, arched dorsally. One large U-shaped frontal scar.

Description.—Valve rhomboidal in lateral view. Anterior margin evenly rounded; dorsal and ventral margins straight in male forms, arched in female forms; posterior margin truncated obliquely in upper half and lower half making blunt angle slightly above mid-height. Strong sexual dimorphism; in lateral view, male forms more elongate; in dorsal view, carapaces of female forms inflated in lateral outline. Eye spot not observed. Surface ornamented by punctations in the anterior area, polygonal reticulations and secondary reticulations in the median and posterior areas. Three concentric muri occur in the anteroventral area, convex ventrally in the mid-ventral area, ends at mid-posterior area. One prominent murus runs from the mid-dorsal area to the posterodorsal area, arched dorsally. In dorsal view, carapace ovate, widest at mid-length, pointed at the anterior and posterior ends. In anterior view, carapace subovate, broadest a little below mid-height. Marginal zone broad anteriorly and posteriorly, with developed vestibula. Marginal pore canals straight, number 6 anteriorly, 11 ventrally, 6 posteriorly. Selvage and list well developed. Hinge gongylodont: In LV, anterior element is a downturned claw-shaped ridge around a socket; median element is a smooth bar; posterior element is a horseshoe-shaped socket around a ball-like knob. One large U-shaped frontal scar. Four adductor scars in a vertical row (the upper three are elliptical, the lowermost one is semicircular). Two elliptical mandibular scars. Five elliptical dorsomedian dorsal scars. Prominent fulcral point.

Remarks.—This species differs from *Loxoconcha (Palmoconcha) parapontica* Zhou, 1995 from the Recent sediments of Kumano-nada and Hyuga-nada, southwest Japan, in its anterior marginal outline and punctations in the anterior area. *P. irizukii* is distinguished from *P. saboyamensis* (Ishizaki, 1966) from the Middle Miocene Hatatate Formation of northeast Japan, in the outline of the anterior margin and the three concentric muri running toward the mid-posterior area.

Occurrences.—Middle Miocene sediments, Honshu, Japan (M5a and M9e; see Figure 4).

Acknowledgements

The authors express their deep gratitude to N. Ikeya, A.

Tsukagoshi (Shizuoka University) and T. Irizuki (Aichi University of Education) for advice and continuous encouragement throughout the course of the present study. Thanks are also due to R. M. Ross (Paleontological Research Institution, New York), R. J. Smith (Kanazawa University) and K. M. Satish (Shizuoka University) for reading our manuscript. This manuscript was improved by two anonymous referees. We thank K. Tanehira (Shimane), K. Kitakaze (Hiroshima), T. Kosaka (Hiroshima University) and the members of the Cenozoic Environmental Seminar and the Paleontological Seminar (Shimane University) for their fieldwork assistance.

References

Apostolescu, V., 1961: Contribution à l'étude paléontologique (Ostracodes) et stratigraphique des bassins crétacés et tertiaires de l'Afrique Occidentale. *Revue de l'Institut Français du Pétrole et Annales des Combustibles Liquides*, vol. 16, nos. 7/8, p. 779-867.

Athersuch, J., Horne, D. J. and Whittaker, J. E., 1989: Marine and brackish water Ostracods (Superfamilies Cypridacea and Cytheracea). *In*, Kermack, D. M. and Barnes, R. S. K. *eds.*, *Synopses of the British Fauna (New Series)*, no. 43, p. 1-343. The Linnean Society of London and the Estuarine and Brackish-Water Sciences Association.

Baird, W., 1850: *The Natural History of the British Entomostraca*, 364 p. Ray Society, London.

Bassiouni, M. E. A. A., 1965: Über einige Ostracoden aus dem Interglazial von Esbjerg. *Meddelelser fra Dansk Geologisk Forening*, vol. 15, no. 4, p. 507-520.

Bold, W. A. Van den, 1957: Ostracoda from the Paleocene of Trinidad. *Micropaleontology*, vol. 3, no. 1, p. 1-18.

Brady, G. S., 1868: A monograph of the Recent British Ostracoda. *Linnean Society of London Transactions*, vol. 26, no. 2, p. 353-495.

Brouwers, E. M., 1988: Palaeobathymetry on the continental shelf based on examples using ostracods from the Gulf of Alaska. *In*, De Deckker, P., Colin, J. P. and Peypouquet, J. P. *eds.*, *Ostracoda in the Earth Sciences*, p. 55-76. Elsevier, Amsterdam.

Brouwers, E. M., 1990: Systematic paleontology of Quaternary ostracode assemblages from the Gulf of Alaska, Part 1: Families Cytherellidae, Bairdiidae, Cytheridae, Leptocytheridae, Limnocytheridae, Eucytheridae, Krithidae, Cushmanideidae. *U. S. Geological Survey Professional Paper* 1510, p. 1-43.

Brouwers, E. M., 1993: Systematic paleontology of Quaternary ostracode assemblages from the Gulf of Alaska, Part 2: Families Trachyleberididae, Hemicytheridae, Loxoconchidae, Paracytherideidae. *U. S. Geological Survey Professional Paper* 1531, p. 1-47.

Brouwers, E. M., Jørgensen, N. O. and Cronin, T. M., 1991: Climatic significance of the ostracode fauna from the Pliocene Kap København Formation, north Greenland. *Micropaleontology*, vol. 37, no. 2, p. 1-23.

Caralp, M., Klingebiel, A., Lamy, A., Latouche, C., Moyes, J. and Vigneaux, M., 1968: Étude micropaléontologique, sedimentologique et geochimique de quelques carottes de sediments recents du Golfe de Gascogne. *Bulletin de l'Institut de Géologie du Bassin d'Aquitaine*, no. 5, p.3-73.

Caralp, M., Moyes, J. and Vigneaux, M., 1967: La microfaune actuelle et subrécente d'une carotte atlantique (golfe de Gascogne): observations écologiques et climatiques. *Bulletin de la Société Géologique de France, Série 7*, vol. 9, p. 418-425.

Cheong, H. K., Lee, E. H., Paik, K. H. and Chang, S. K., 1986: Recent ostracodes from the southwestern slope of the Ulleung Basin, East Sea, Korea. *Journal of the Paleontological Society of Korea*, vol. 2, no. 1, p. 38-53.

Chinzei, K., 1986: Faunal succession and geographic distribution of Neogene molluscan faunas in Japan. *In*, Kotaka, T. *ed.*, *Japanese Cenozoic Molluscs: Their Origin and Migration, Palaeontological Society of Japan, Special Papers*, no. 29, p. 17-32.

Cronin, T. M., 1981: Paleoclimatic implications of Late Pleistocene marine ostracodes from the St. Lawrence Lowlands. *Micropaleontology*, vol. 27, no. 4, p. 384-418.

Cronin, T. M., 1986: Paleozoogeography of Post-glacial Ostracoda from Northeastern North America. *In*, Gadd, N. R. *ed.*, *The Champlain Sea. Geological Survey of Canada, Special Paper*, p. 1-39.

Cronin, T. M., 1989: Paleozoogeography of Postglacial Ostracoda from Northeastern North America. *In*, Gadd, N. R. *ed.*, *The Late Quaternary Development of the Champlain Sea Basin Sea. Geological Association of Canada, Special Paper*, no. 35, p. 125-144.

Cronin, T. M., 1991: Late Neogene marine Ostracoda from Tjörnes, Iceland. *Journal of Paleontology*, vol. 65, no. 5, p. 767-794.

Cronin, T. M. Compton-Gooding, E. E., 1987: 16. Cenozoic Ostracoda from Deep Sea Drilling Project Leg 95 off New Jersey (Sites 612 and 613). *In*, Poag, C. W. *et al.*, *Initial Reports of the Deep Sea Drilling Project*, Volume 95, p. 439-451. U.S. Government Printing Office, Washington, D. C.

Cronin, T. M. and Ikeya, N., 1987: The Omma-Manganji ostracod fauna (Plio-Pleistocene) of Japan and the zoogeography of circumpolar species. *Journal of Micropalaeontology*, vol. 6, no. 2, p. 65-88.

Deroo, G., 1966: Cytheracea (Ostracodes) du Maastrichtien de Maastricht (Pays-Bas), et des régions voisines; résultats stratigraphiques et paléonotologiques de leur étude. *Medelingen Geologische Stichting, Serie C*, vol. 2, no. 2, p. 1-197.

Elofson, O., 1941: Zur Kenntnis der marinen Ostracoden Schwedens mit besonderer Berücksichtigung des Skageraks. *Zoologiska Bidrag från Uppsala*, band. 19, p. 215-534.

Elofson, O., 1943: Neuere Beobachtungen über die Verbreitung der Ostracoden an den skandinavischen Küsten. *Arkiv för zoologie*, vol. 35A, no. 2, p. 1-26.

Freiwald, A. and Mostafawi, N., 1998: Ostracods in a cold-temperate costal environment, Western Troms, Northern Norway: Sedimentary aspects and assemblages. *Facies*, 38, p. 255-274.

Hanai, T. 1957a: Studies on the Ostracoda from Japan, I. Subfamily Leptocytherinae, new subfamily. *Journal of the Faculty of Science, University of Tokyo, Section 2*, vol. 10, pt. 3, p. 431-468.

Hanai, T. 1957b: Studies on the Ostracoda from Japan, II. Subfamily Pectocytherinae, new subfamily. *Journal of the Faculty of Science, University of Tokyo, Section* 2, vol. 10, pt. 3, p. 469-482.

Hanai, T., 1961: Studies on the Ostracoda from Japan: Hingement. *Journal of the Faculty of Science, University of Tokyo, Section 2*, vol. 13, pt. 2, p. 345-377.

Hanai, T., 1970: Studies on the ostracod subfamily Schizocytherinae Mandelstam. *Journal of Paleontology*, vol. 44, no. 4, p. 693-729.

Hartmann, G., 1992: Zur Kenntnis der rezenten und subfossilen Ostracoden des Liefdefjords (Nordspitzbergen, Svålbard). 1. Teil. Mit einer Tabelle subfossil nachgewiesener Föraminiferen: Ergebnis der Geowissenschftlichen Spitzbergen-Expedition 1990. *Mitteilung aus dem Hamburgischen Zoologischen Museum und Institut*, no. 89, p. 181-225.

Hartmann, G., 1993: Zur Kenntnis der rezenten und subfossilen Ostracoden des Liefdefjords (Nordspitzbergen, Svålbard), 2. Teil: Ergebnisse der Geowissenschaftlichen Spitzbergen Expedition 1991. *Mitteilung aus dem Hamburgischen Zoologischen Museum und Institut*, no. 90, p. 239-250.

Hartmann, G. and Puri, H. S., 1974: Summary of neontological and palaeontological classification of Ostracoda. *Mitteilung aus dem Hamburgischen Zoologischen Museum und Institut*, no. 70, p. 7-73.

Hazel, J. E. and Valentine, P., 1969: Three new ostracodes from off northeast North America. *Journal of Paleontology*, vol. 43, no. 3, p. 741-752.

Hirschmann, N., 1916: Ostracoda of the Baltic Sea collected by N. M. Knipovitch and S. A. Pavlovitch in the Summer of 1908. *St. Petersburg, Ezhegodnik Zoologicheskago Muzeya Imperatorskoy Akademii Nauk (Annuaire du Musée Zoologique de l' Academie Imperiale des Sciences)*, vol. 20, p. 569-597. *(in Russian)*

Horne, D. J., 1983: On *Robertsonites tuberculatus* (Sars). *In*, Bate, R. H., *et al. eds.*, *A Stereo-Atlas of Ostracod Shells*, vol. 10, no. 8, p. 39-52.

Howe, H. V., 1963: Type Saline Bayou Ostracoda of Louisiana. *Louisiana Geological Survey, Geological Bulletin*, vol. 40, p. 1-62.

Huh, M. and Paik, K. H., 1992a: Miocene Ostracoda from the Seojeongri Area, Pohang Basin, Korea. *Journal of the Geological Society of Korea*, vol. 28, no. 3, p. 273-283. *(in Korean with English abstract)*

Huh, M. and Paik, K. H., 1992b: Miocene Ostracoda from the Pohang Basin, Korea. *Paleontological Society of Korea, Special Publication*, no. 1, p. 101-119.

Huh, M. and Whatley, R., 1997: New species of Miocene cytheracean Ostracoda from the Pohang Basin, SE Korea. *Journal of Micropalaeontology*, vol.16, pt. 1, p. 31-40.

Hulings, N. C., 1967: Marine Ostracoda from the western North Atlantic Ocean: Labrador Sea, Gulf of St. Lawrence and off Nova Scotia. *Crustaceana*, vol. 13, part 3, p. 310-328.

Ikeya, N. and Cronin, T. M., 1993: Quantitative analysis of Ostracoda and water masses around Japan: Application to Pliocene and Pleistocene paleoceanography. *Micropaleontology*, vol. 39, no. 3, p. 263-281.

Ikeya, N. and Itoh, H., 1991: Recent Ostracoda from the Sendai Bay region, Pacific coast of northeastern Japan. *Reports of Faculty of Science, Shizuoka University*, vol. 25, p. 93-145.

Ikeya, N. and Suzuki, C., 1992: Distributional patterns of modern ostracodes off Shimane Peninsula, southwestern Japan Sea. *Reports of Faculty of Science, Shizuoka University*, vol. 26, p. 91-137.

Irizuki, T., 1994: Late Miocene ostracods from the Fujikotogawa Formation, northern Japan—with reference to cold water species involved with trans-Arctic interchange. *Journal of Micropalaeontology*, vol. 13, pt. 1, p. 3-15.

Irizuki, T., 1996: Lithology and Ostracoda from the Pliocene Tentokuji Formation along the southern marginal area of Mt. Taiheizan, Akita Prefecture, Northeast Japan. *Bulletin of Aichi University of Education (Natural Science)*, vol. 45, p. 23-32.

Irizuki, T., Ishizaki, K., Takahashi, M. and Usami, M., 1998: Ostracode faunal changes after the mid-Neogene climatic optimum elucidated in the Middle Miocene Kobana Formation, Central Japan. *Paleontological Research*, vol. 2, no. 1, p. 30-46.

Irizuki, T. and Matsubara, T., 1994: Vertical changes of depositional environments in the Lower to Middle Miocene Kadonosawa Formation based on analyses of fossil ostracode faunas. *Journal of the Geological Society of Japan*, vol. 100, no. 2, p. 136-149. *(in Japanese with English abstract)*

Irizuki, T. and Matsubara, T., 1995: Early Middle Miocene ostracodes from the Suenomatsuyama Formation, Ninohe City, Northeast Japan and their paleoenvironmental significance. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 177, p. 65-78.

Ishizaki, K., 1963: Japanese Miocene ostracodes from the Sunakosaka Member of the Yatsuo Formation, east of Kanazawa City, Ishikawa Prefecture. *Japanese Journal of the Geology and Geography*, vol. 34, no. 1, p. 19-34.

Ishizaki, K., 1966: Miocene and Pliocene ostracodes from the Sendai Area, Japan. *Science Reports of the Tohoku University, Second Series (Geology)*, vol. 37, no. 2, p. 131-163.

Ishizaki, K., 1971: Ostracodes from Aomori Bay, Aomori Prefecture, Northeast Honshu, Japan. *Science Reports of the Tohoku University, Second Series (Geology)*, vol. 43, no. 1, p. 59-97.

Ishizaki, K., Fujiwara, O. and Irizuki, T., 1996: Ostracod faunas from the Upper Miocene Tsunaki Formation near the southern border of Sendai City, Northeast Japan. *Proceedings of the Second European Ostracodologists Meeting*, p. 113-120.

Ishizaki, K. and Matoba, Y., 1985: Akita (Early Pleistocene cold shallow water Ostracoda). *In*, Organizing Committee of 9th International Symposium on Ostracoda, *9th International Symposium on Ostracoda Guidebook (Excursion 5)*, p. 1-12. Shizuoka University Press, Shizuoka.

Kamiya, T. and Nakagawa, T., 1993: Ostracode fossil assembleges in the Holocene shell bed found in Takahama-cho, Fukui Prefecture, Central Japan. *Bulletin of the Fukui City Natural Museum*, no. 1, p. 115-133.

Kamiya, T., Ozawa, H. and Kitamura, A., 1996: Paleo-water mass structure during the deposition of middle part of the Omma Formation based on the change of ostracode assemblage. *Hokuriku Geology Institute Report*, no. 5, p. 145-165.

Kano, K., Yamauchi, S., Takayasu, K., Matsuura, H. and Bunno, M., 1994: *Geology of the Matsue District. Quadrangle Series Scale 1:50,000, Okayama (12)*, no. 17, p. 1-126. Geological Survey of Japan, Tsukuba. *(in Japanese with English abstract)*

Kingma, J. T., 1948: *Contributions to the Knowledge of the Young-Caenozoic Ostracoda from the Malayan Region*, 119 p. Kemink Printers, Utrecht.

Lord, A. R., 1980: Weichselian (Late Quaternary) ostracods from the Sandnes Clay, Norway. *Geological Magazine*, vol. 117, no. 3, p. 227-242.

Maiya, S. and Inoue, Y., 1973: On the effective treatment of rocks for microfossil analysis. *Fossils (Palaeontological Society of Japan)*, nos. 25/26, p. 87-96. *(in Japanese with English abstract)*

Malz, H., 1982: Plio-/Pleistozäne Buntoniini von SW-Taiwan. *Senckenbergiana Lethaea*, vol. 63, nos. 5/6, p. 377-411.

Mandelstam, M. J., 1960: Ostracoda. *In*, Tschernysheva, E. N. *ed., Fundamentals of Paleontology, Arthropoda Volume*, p. 264–421. State Scientific Technology Publishing House, Moskow. (*in Russian*)

McDougall, K., Brouwers, E.M. and Smith P., 1986: Micropaleontology and sedimentology of the PB Borehole Series, Prudhoe Bay, Alaska. *U.S. Geological Survey Bulletin* 1598, p. 1–62.

McKenzie, K. G., Majoran, S., Emami, V. and Reyment, R. A., 1989: The *Krithe* problem—First test of Peypouquet's hypothesis, with a redescription of *Krithe praetexta praetexta* (Crustacea, Ostracoda). *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 74, p. 343–354.

Neale, J. W., 1973: *Cluthia* (Crustacea: Ostracoda), a new Pleistocene and Recent Leptocytherid genus. *Journal of Paleontology*, vol. 47, no. 4, p. 683–688.

Neale, J. W. and Howe, H. V., 1975: The marine Ostracoda of Russian Harbour, Novaya Zemlya and other high latitude faunas. *In*, Swain, F. M. *ed., Biology and Paleobiology of Ostracoda, Bulletins of American Paleontology*, vol. 65, no. 282, p. 381–431.

Nomura, R. and Maiya, S., 1984: Geologic age of the Fujina Formation, Shimane Prefecture, based on planktonic foraminifera. *Memoirs of Natural and Cultural Researches of the San-in Region, Shimane University*, no. 24, p. 1–9. (*in Japanese*)

Norman, A. M., 1865a: Deep-sea dredging on the coasts of Northumberland and Durham in 1864. *British Association for the Advancement of Science Report, 34th Meeting*, p. 189–193.

Norman, A. M., 1865b: Report on the Crustacea. *In*, Brady, G. S. *ed., Reports of the Deep-sea Dredging off the Coasts of Northumberland and Durham*, p. 12–29. *Transactions of the Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne, London.*

Ogasawara, K. and Nomura, R., 1980: Molluscan fossils from the Fujina Formation, Shimane Prefecture, San-in district, Japan. *In*, Igo, H. and Noda, H. *eds., Professor Saburo Kanno Memorial Volume*, p. 79–98. Sasaki Shuppan Co., Sendai.

Otofuji, Y. and Matsuda, T., 1984: Timing of rotational motion of southwest Japan inferred from paleomagnetism. *Earth and Planetary Science Letters*, vol. 70, p. 373–382.

Ozawa, H., 1996: Ostracode fossils from the Late Pliocene to Early Pleistocene Omma Formation in the Hokuriku district, central Japan. *Science Reports of Kanazawa University*, vol.41, no. 2, p. 77–115.

Ozawa, H., Kamiya, T. and Tsukagoshi, A., 1995: Ostracode evidence for the paleoceanographic change of the Middle Pleistocene Jizodo and Yabu Formations in the Boso Peninsula, central Japan. *Science Reports of Kanazawa University*, vol. 40, no. 1, p. 9–37.

Penney, D. N., 1993: Late Pliocene to Early Pleistocene ostracod stratigraphy and palaeoclimate of the Lodin Elv and Kap København formations, East Greenland. *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 101, p. 49–66.

Puri, H. S., 1953: The ostracod genus *Hemicythere* and its allies. *Washington Academy of Sciencecs Journal*, vol. 43, no. 6, p. 169–179.

Puri, H. S., 1954: Contribution to the study of the Miocene of the Florida Panhandle. Pt. 3, Ostracoda. *The Florida Geological Survey, Geological Bulletin*, no. 36, p. 215–345.

Rosenfeld, A., 1977: Die rezenten Ostracoden-Arten in der Ostsee. *Meyniana*, vol. 29, p. 11–49.

Ruan, P. and Hao, Y., 1988: 2. Ostracoda. *In*, Research Party of Marine Geology, Ministry of Geology and Mineral Resources, Chinese University of Geoschiences *eds., Quaternary Microbiotas in the Okinawa Trough and their Geological Significance*, p. 227–395. Geological Publishing House, Beijing, China. (*in Chinese with English abstract*)

Ruggieri, G., 1950: Gli Ostracodi delle sabbie grigie quaternarie (Milazziano) di Imola. Parte 1. *Giornale di Geologia, Annali del Museo Geologico di Bologna*, serie 2, vol. 21, p. 1–58.

Ruggieri, G., 1953: Età e fauna di un terrazzo marino sulle costa ioniche della Calabria. *Giornale di Geologia, Annali del Museo Geologico di Bologna, Serie 2a*, vol. 23, p. 17–168.

Sakumoto, T., Seto, K. and Takayasu, K., 1996: Fossil cephalopods from the Middle Miocene Fujina Formation of southwest Japan and its paleoenvironmental significance. *Earth Science (Chikyu Kagaku)*, vol. 50, p. 408–413. (*in Japanese with English abstract*)

Sars, G. O., 1866: Oversigt af Norges marine Ostracoder: Forhandlinger I. *Videnskabs-Selskabet Christiania*, vol. 8, p. 1–130.

Sars, G. O., 1926: *An Account of the Crustacea of Norway, 9 Ostracoda.* Parts 13 and 14, p. 209–240. Bergen Museum, Bergen.

Scott, H. W., 1961: Shell morphology of Ostracoda. *In*, Moore, R. C. *ed., Treatise on Invertebrate Paleontology Part Q. Arthropoda 3 Crustacea, Ostracoda*, Q21–Q37. Geological Society of America and University of Kansas Press.

Swain, F. M., 1961: Ostracoda from the Pleistocene Gubik Formation, Arctic Coastal Plain, Alaska. *In*, Raasch, G. O. *ed., Geology of the Arctic*, vol. 1, p. 600–606. University of Toronto Press, Toronto.

Swain, F. M., 1963: Pleistocene Ostracoda from the Gubik Formation, Arctic Coastal Plain, Alaska. *Journal of Paleontology*, vol. 37, no. 4, p. 798–834.

Swain, F. M. and Gilby, J. M., 1974: Marine Holocene Ostracoda from the Pacific coast of North and Central America. *Micropaleontology*, vol. 20, no. 2, p. 257–352.

Sylvester-Bradley, P. C., 1948: The ostracode genus *Cythereis*. *Journal of Paleontology*, vol. 22, no. 6, p. 792–797.

Tabuki, R., 1986: Plio-Pleistocene Ostracoda from the Tsugaru Basin, North Honshu, Japan. *Bulletin of College of Education, University of the Ryukyus*, no. 29, p. 27–160.

Takayasu, K., 1986: Diversification in the molluscan fauna of the Miocene Izumo Group, San-in district, Southwest Japan. *In*, Kotaka, T. *ed., Japanese Cenozoic Molluscs: Their Origin and Migration, Palaeontological Society of Japan, Special Papers*, no. 29, p. 173–186.

Takayasu, K. and Nakamura, T., 1984: Desmostylia bearing beds in the southern-border of Lake Shinji, West Japan, and their paleoenvironments from the viewpoint of molluscan fossils. *In*, Inuzuka, N. *et al eds., Desmostylians and their Paleoenvironments, Monograph 28, Association for the Geological Collaboration*, p. 91–99. (*in Japanese with English abstract*)

Takayasu, K., Yamasaki, H., Ueda, T., Akagi, S., Matsumoto, T., Nomura, R., Okada, S., Sawada, Y., Yamauchi, S. and Yoshitani, A., 1992: Miocene stratigraphy and paleogeography of San'in district, Southwest Japan. *Memories of the Geological Society of Japan*, no. 37, p. 97–116. (*in Japanese with English abstract*)

Tomita, T. and Sakai, E., 1937: Cenozoic geology of the Huzina-Kimati district, Izumo province, Japan: A contribution to the igneous geology of the East-Asiatic province of Cenozoic alkaline rocks. *Journal of the Shanghai Science Institute, Section 2, Geology, Palaeontology, Mineralogy and Petrology*, vol. 2, 147–204.

Tressler, W. L., 1941: Geology and biology of North Atlantic deep sea cores between Newfoundland and Ireland, part 4, Ostracoda. *U. S. Geological Survey Professional Paper* 196-C, p. 95-103.

Triebel, E., 1949: Mikropaläontologische Kennzeichnung der Ostracoden-Gattungen *Xenocythere* und *Palmenella*. *Senckenbergiana*, vol. 30, nos. 4/6, p. 185-192.

Wagner, F. J. E., 1970: Faunas of the Pleistocene Champlain Sea. *Geological Survey of Canada Bulletin* no. 181, p. 1-104.

Yajima, M., 1982: Late Pleistocene Ostracoda from the Boso Peninsula, central Japan. *In*, Hanai, T. *ed.*, *Studies on Japanese Ostracoda, University Museum, University of Tokyo, Bulletin*, no. 20, p. 141-227.

Yajima, M., 1988: Preliminary notes on the Japanese Miocene Ostracoda. *In*, Hanai, T., Ikeya, N. and Ishizaki, K. *eds.*, *Evolutionary Biology of Ostracoda—its Fundamentals and Applications*, p. 1073-1085. Kodansha, Tokyo.

Yajima, M., 1992: Early Miocene Ostracoda from Mizunami, Central Japan. *Bulletin of the Mizunami Fossil Museum*, no. 19, p. 247-268.

Yajima, M. and Lord, A., 1990: The interpretation of Quaternary environments using Ostracoda: an example from Japan. *Proceedings of the Geologists' Association*, vol. 101, no. 2, p. 153-161.

Zhou, B., 1995: Recent ostracode fauna in the Pacific off Southwest Japan. *Memoirs of the Faculty of Science of Kyoto University Series of Geology and Mineralogy*, vol. 57, no. 2, p. 21-98.