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Five new species of the genus *Semisulcospira* (Mollusca: Caenogastropoda: Semisulcospiridae) from the Pleistocene Katata Formation of the Kobiwako Group, Shiga Prefecture, central Japan

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Abstract

Five new species of the freshwater snail genus *Semisulcospira* are described from the Pleistocene Katata Formation of the Kobiwako Group in central Japan. *Semisulcospira* contains two subgenera, *Semisulcospira* and *Biwamelania*, and these five new species belong to the subgenus *Biwamelania*. *Semisulcospira* (*Biwamelania*) *nakamurai* nov. sp., *Semisulcospira* (*Biwamelania*) *pseudomultigranosa* nov. sp., *Semisulcospira* (*Biwamelania*) *spinulifera* nov. sp., *Semisulcospira* (*Biwamelania*) *kokubuensis* nov. sp., and *Semisulcospira* (*Biwamelania*) *pusilla* nov. sp. are described herein. These species appear to be the direct ancestors of fifteen extant species of *Biwamelania* that have been diversified in Lake Biwa for the last approximately 400,000 years; then, these occurrences can provide valuable information to understand the history of diversification of *Biwamelania* species in Lake Biwa.

Key words: Freshwater snail, Mollusca, Semisulcospiridae, *Semisulcospira*, *Biwamelania*, Kobiwako Group, Pleistocene, Lake Biwa, Japan

Introduction

The genus *Semisulcospira* Boettger, 1886 is widely distributed and one of the most abundant molluscs in freshwater environments of East Asia (Davis, 1969; Burch *et al*., 1987; Strong and Köhler, 2009). Davis (1969) carefully studied the morphological characters of several living species of *Semisulcospira* in Japan and divided them into two distinct groups: the *Semisulcospira libertina* group and the *Semisulcospira niponica* group. Matsuoka and Nakamura (1981) later recognized the subgeneric rank for two groups. The subgenus *Semisulcospira* corresponded with the *S. libertine* group and the new subgenus *Biwamelania* were proposed for the *S. niponica* group (Matsuoka and Nakamura, 1981). The subgenus *Biwamelania* is distinguishable from the subgenus *Semisulcospira* by having a conical, elongated shell with fewer (2–6) basal cords and larger and fewer embryos (Matsuoka, 1985a).

There are fifteen living species in the subgenus *Biwamelania* (Watanabe and Nishino, 1995; Nishino and Watanabe, 2000). While the subgenus *Biwamelania* is currently endemic to Lake Biwa and its drainage, the fossil species of *Biwamelania* has a broader distribution range in Tokai, Kinki, and Kyushu regions during the Pliocene and Pleistocene (Matsuoka and Nakamura, 1981; Matsuoka, 1985b; Matsuoka and Kitabayashi, 2001; Matsuoka, 2013). At least eight morphologically distinct forms of *Biwamelania* have been recognized as fossils from the Kobiwako Group in Japan (Matsuoka, 1987). Of those forms, *Semisulcospira* (*Biwamelania*) *praemultigranosa* Matsuoka, 1985 was only described from the Pliocene Iga Formation that is the lower part of the Kobiwako Group (Matsuoka, 1985a). However, other forms have not yet been described.

In this study, we describe two fossil species of *Biwamelania* from the Pleistocene Katata Formation mainly distributed to the Katata Hills in Shiga Prefecture. Furthermore, we also describe other three species from the Katata Formation of Kokubu, Otsu City.

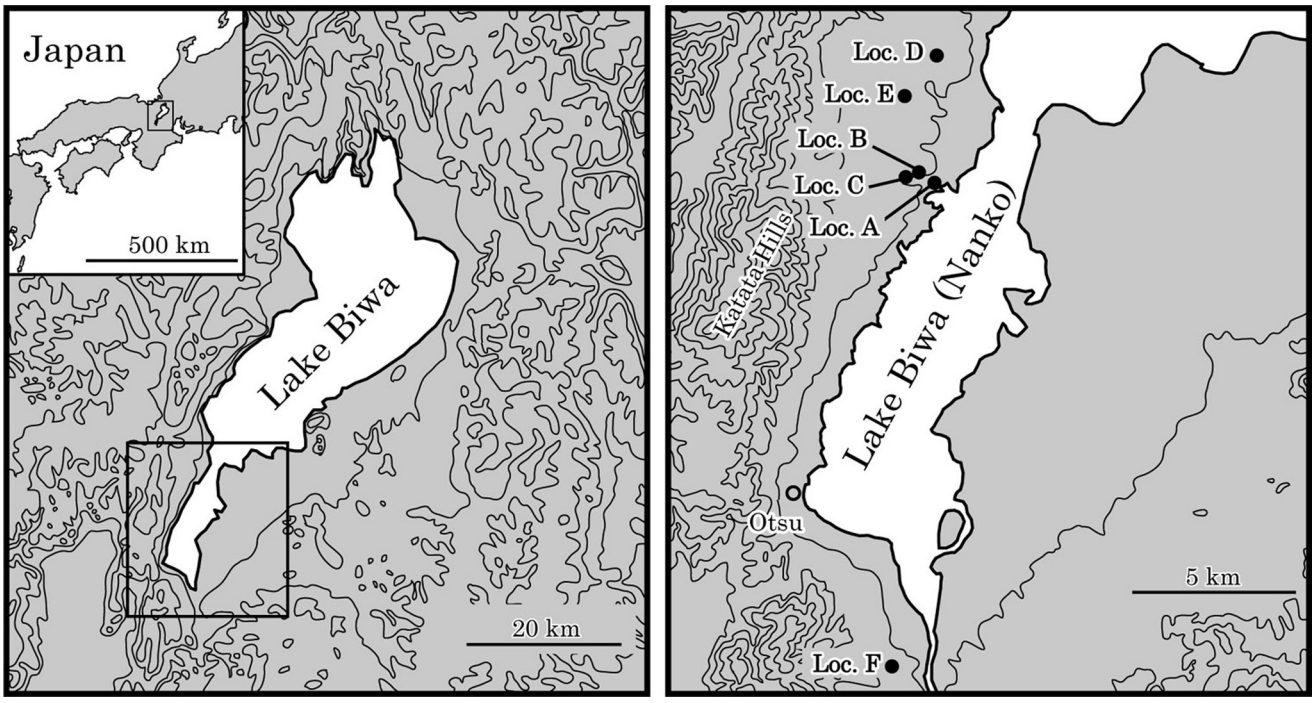


Fig. 1. Sampling localities on Katata Hills (Loc. A–E) and on Kokubu, Otsu City, Shiga Prefecture (Loc. F).

Localities and Methods

The Katata Formation of the Kobiwako Group is distributed in the Katata Hills and the Kokubu area to the south of Lake Biwa. Studied materials including type specimens were obtained six localities in the Katata Hills and the Kokubu area (Fig. 1). This formation is composed of massive mud and alternating layers of sand and mud. The massive muddy sediments demonstrate the past existence of stable lake, Paleo-ancient Lake Katata. Hayashi (1974) divided the Katata Formation into eight members in ascending order: Nijigaoka Clays, Kitahama Sands, Kisen Clays, Takashiro Alternations, Hiraen Clays, Kurihara Alternations, Sakawa Clays, and Ryuge Sands and Gravels. The Katata Formation was deposited between early to middle Pleistocene (about 1.2 Ma to 0.5 Ma) based on the Fission Track dating method and magnetostratigraphy (*e.g.* Yoshikawa, 1984; Kamata *et al*., 1994; Danhara *et al*., 1997; Satoguchi, 2012).

Loc. A: Exposures created by the construction of a housing complex of Kinukawadai, Kinukawa, Otsu City (lat. 35°6'24" N, long. 135°54'26"E). The fossiliferous bed constitutes grayish massive silt four to five meters above the Sakawa Ⅱ volcanic ash layer interbedded in the Sakawa Clays, most upper part of the Katata Formation. Matsuoka and Nakamura (1981) briefly described 18 species including the semisulcospirid gastropods: *Semisulcospira* (*Biwamelania*) sp. 1, *S.* (*B.*) sp. 2 and *S.* (*B.*) sp. 3. One form, *S.* (*B.*) sp. 3 in Matsuoka and Nakamura (1981), was later recognized as the extant species, *S.* (*B.*) *habei* Davis, 1969 (Matsuoka, 1986) .

Loc. B: An exposure created by construction of a road, about 750 m east southeast of Shimoogi, Ogi-cho, Otsu City (lat. 35°6'28"N, long. 135°54'0"E). Matsuoka (1983) reported *S.* (*B.*) sp. 1 and *S.* (*B.*) sp. 2 from blueish gray massive clay of the Sakawa Clays, in which the Sakawa Ⅱ volcanic ash layer (most upper part of the Katata Formation) is interbedded.

Loc. C: An exposure created by the construction of a housing complex, about 800 m southeast of Ogi-cho, Otsu City (lat. 35°6'24"N, long. 135°53'50"E).

The fossil-bearing bed is grayish massive silt about 6 m below the Sakawa Ⅱ volcanic ash layer, most upper part of the Katata Formation. Matsuoka (1986) has reported two semisulcospirid species, *S.* (*B.*) *habei* and *S.* (*B.*) sp. 1.

Loc. D: An exposure created by the construction of a housing complex, about 1 km northeast of Manosakawa-cho, Otsu City (lat. 35°8'28"N, long. 135°54'30"E).

Fossils were obtained from grayish massive silt in the Hiraen Clays of the upper part of the Katata Formation, in which the Biotite Ⅱ volcanic ash layer is intercalated, and from silty–fine-grained sand three meters below the volcanic ash layer. The semisulcospirid fossils found at this site are *S.* (*B.*) sp. 2, *S.* (*B.*) sp. 3 and *S.* (*B.*) *habei* (Matsuoka, 1986).

Loc. E: Roadside about 400 m west of Manoono-cho, Otsu City (lat. 35°7'48"N, long. 135°53'49"E). The fossil *Alocinma longicornis* (Benson) (=*Gabbia longicornis*) and embryonic shells of *Semisulcospira* spp. were found from the boring core sample made at the present locality (Yasuno, 1980; Matsuoka, 1981). The fossiliferous sediments may be correlative with some horizon in the Hiraen Clays (upper part of the Katata Formation).

Loc. F : Muddy fossiliferous bed about 20 m below ground, Kokubu, Otsu City, Shiga Prefecture was made at the present locality (lat. 34°58'13"N, long. 135°53'33"E). The fossiliferous bed constitutes some horizon about the Ikenouchi Ⅱ volcanic ash layer interbedded to the Zeze Formation, in which correlated to the lower part of the Nijigaoka Clays, a lower part of the Katata Formation (Yoshikawa, 1984; Kobiwako Research Group, 1992). The viviparid gastropod, *Heterogen longispira* is predominant in the fossiliferous bed, in which contains a subordinate amount of *S.* (*B.*) spp., *Gabbia longicornis*, and their accompanied unionid bivalves.

We measured shell height and shell width of fossils collected from above-mentioned localities using calipers to 0.01 mm. We also photographed the samples using digital camera DP26 (Olympus Co., Tokyo, Japan) mounted on stereomicroscope. The measurements of angles were made with these images and using the software cellSens (Olympus Co., Tokyo, Japan).

Presence of embryonic shells were examined using micro-CT Xradia scanner (Carl Zeiss X-ray Microscopy Inc., CA, USA) and HMX225-ACTIS+3 (Tesco Co., Kanagawa Japan) at Center for Advanced Marine Core Research (Kochi University, Japan). We identified the specimens that have embryonic shells by inspecting the CT images using the software 3D Slicer (https://www.slicer.org/). The adult shells containing embryonic shells were then soaked into water and we injected water into their aperture with a syringe to pull out the embryonic shells. We photographed the embryonic shells under the stereomicroscope and digital camera system mentioned above. We measured the length and width of the digitalized embryonic shell using the software cellSens. For the embryos which were not pulled out by the above method, we obtained detailed CT images by Xradia scanner at high magnification and visualized them by the volume rendering module of 3D Slicer.

Systematic descriptions

Fossil specimens used for this study are deposited in paleontological collections of the Toyohashi Museum of Natural History (TMNH), Toyohashi City, Aichi Prefecture, the Lake Biwa Museum (LBM), Kusatsu City, Shiga Prefecture, and the Mizunami Fossil Museum (MFM), Mizunami City, Gifu Prefecture.

Family Semisulcospiridae Morrison, 1952
Genus *Semisulcospira* Boettger, 1886

Subgenus *Biwamelania* Matsuoka and Nakamura, 1981

Type species: *Melania niponica* var. *decipiens* Westerlund, 1883, by subsequent designation by Matsuoka (1985a).

Diagnosis: Shell small to large in size for this family, conic to elongate conic in outline. Sculpture possessing to nodes and/or spinose on the axial ribs, the orthocline to weakly opisthocline ribs. The basal cords on the body whorl two to six. The embryonic shell large in size, and few in number.

Remarks: The generic name *Biwamelania* was first used by Habe (1978). However, Matsuoka and Nakamura (1981) showed that the name *Biwamelania* was not an available name because the genus was not diagnosed by Habe (1978). Therefore, the authorship of *Biwamelania* was Matsuoka and Nakamura (1981), subsequently used for *Biwamelania*.

The genus *Semisulcospira* was subdivided into two subgenera (Matsuoka and Nakamura, 1981). *Semisulcospira* and *Biwamelania*, and the two subgenera were correlated with Davis (1969)'s *Semisulcospira libertina* Group and *S. niponica* group, respectively (Matsuoka and Nakamura, 1981; Matsuoka, 1985a). *Biwamelania* was proposed for the six extant species of the *S. niponica* group (Davis, 1969).

This subgenus can be distinguished from *Semisulcospira* (s. str.) by having a small number of basal cords, and large and few embryonic shells (Matsuoka and Nakamura, 1981; Matsuoka, 1985a). The following species is assignable to *Biwamelania* in addition to the type species and 14 species in Lake Biwa and its drainage: *Semisulcospira* (*Biwamelania*) *nakasekoae* Kuroda, 1929; *S.* (*B.*) *decipiens* (Westerlund, 1883); *S.* (*B.*) *niponica* (Smith, 1876); *S.* (*B.*) *multigranosa* (Boettger, 1886); *S.* (*B.*) *habei* Davis, 1969; *S.* (*B.*) *reticulata* Kajiyama and Habe, 1961; *S.* (*B.*) *morii* Watanabe, 1984; *S.* (*B.*) *rugosa* Watanabe and Nishino, 1995; *S.* (*B.*) *fluvialis* Watanabe and Nishino, 1995; *S.* (*B.*) *fuscata* Watanabe and Nishino, 1995; *S.* (*B.*) *dilatata* Watanabe and Nishino, 1995; *S.* (*B.*) *shiraishiensis* Watanabe and Nishino, 1995; *S.* (*B.*) *ourense* Watanabe and Nishino, 1995; *S.* (*B.*) *takeshimensis* Watanabe and Nishino, 1995; *S.* (*B.*) *arenicola* Watanabe and Nishino, 1995. The extinct species including in the subgenus is *S.* (*B.*) *praemultigranosa* Matsuoka, 1985; *S.* (*B.*) *nakamurai* nov. sp.; *S.* (*B.*) *pseudomultigranosa* nov. sp.; *S.* (*B.*) *spinulifera* nov. sp.; *S.* (*B.*) *kokubuensis* nov. sp.; *S.* (*B.*) *pusilla* nov. sp.; *S. napoensis* Mansuy, 1912, from the Eocene Yungning Formation, Guangxi-zhuang Autonomous Region, China and *S. aubryana* var. *costellata* Hsü, 1935, from the Pliocene Cijian Formation, Yunnan, China may be assigned to the subgenus *Biwamelania*.

Semisulcospira (*Biwamelania*) *nakamurai*, nov. sp.

(Fig. 2. 1)

Type locality: An exposure created by the construction of a road about 750m east-southeast of Shimoogi, Ogi-cho, Otsu City, Shiga Prefecture (Loc. B in Fig. 1).

Derivation of name: This species is named in honor of Takashi Nakamura who expended great efforts in collecting molluscan fossils from the Katata Hills.

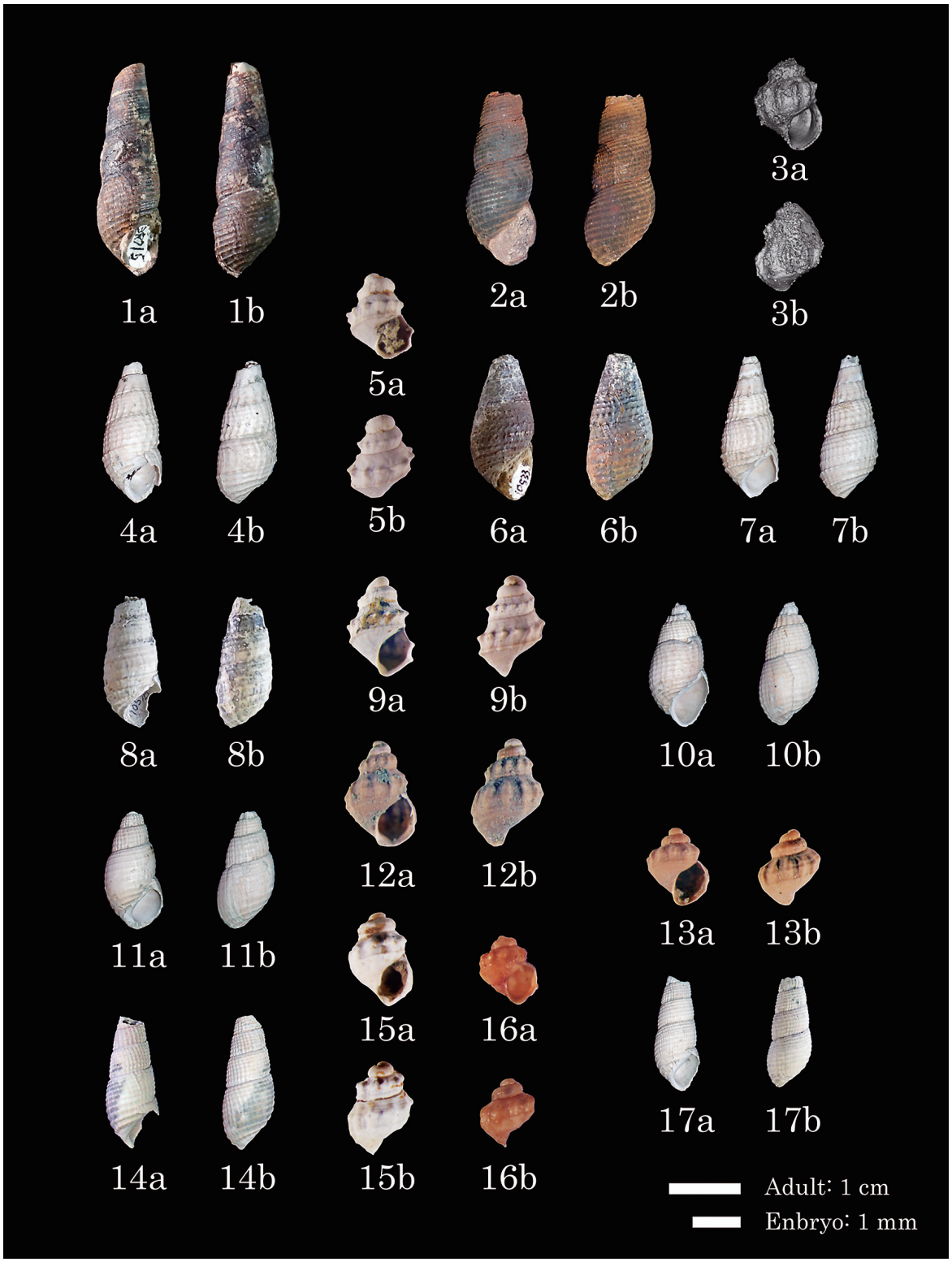


Fig. 2. Shell specimens of five new fossil species. **1. *Semisulcospira* (*Biwamelania*) *nakamurai*.** TMNH10530 (holotype), adult shell. **2, 3. *Semisulcospira* (*Biwamelania*) *pseudomultigranosa*.** 2, TMNH10532 (holotype), adult shell; 3, TMNH10532a (paratype), embryonic shell. **4–9. *Semisulcospira* (*Biwamelania*) *spinulifera*.** 4, TMNH10534 (holotype), Adult shell; 5, TMNH10534a (paratype), embryonic shell; 6, TMNH10533 (paratype), adult shell; 7, LBM0122008711 (paratype), adult shell; 8, TMNH10536 (paratype), adult shell; 9, TMNH10536a (paratype), embryonic shell. **10–13. *Semisulcospira* (*Biwamelania*) *kokubuensis*.** 10, TMNH10544 (paratype), adult shell; 11, TMNH10543 (holotype), adult shell; 12, TMNH 10543a (paratype), embryonic shell; 13, TMNH 10543b (paratype), embryonic shell. **14–17. *Semisulcospira* (*Biwamelania*) *pusilla*.** 14, TMNH10540 (holotype), adult shell; 15, TMNH10540a (paratype), embryonic shell; 16, TMNH10540b (paratype), embryonic shell; 17, LBM0122008723 (paratype 1), adult shell.

Scale bars for adult shells represent 1 cm and those for embryo represent 1 mm. The embryonic shell of *S.* (*B.*) *pseudomultigranosa* (3a, b) is the CT image reconstructed using 3D Slicer.

Material studied: Three specimens. Holotype, TMNH10530; other specimens, TMNH 10531, MFM110055.

Diagnosis: Shell medium, narrowly conic, about four remaining whorls with eroded apex; spiral carinae distinct, seven to nine, axial ribs absent. The suture distinct impressed. The basal cords two to three.

Description: Shell medium for this genus, narrowly conic. Spire high turreted lacking the embryonic and early postembryonic shell; the apical angle about 11.0 degree in average. Apex eroded, about four whorls remaining. The whorl profile flat-sided, and the periphery weekly convex. The suture distinct impressed, not undulate. Sculpture of spire consisting of many distinct spiral carinae, the number of primary carinae on a whorl seven to eight with one secondary carina. Basal cords strong, two to three. Axial ribs absent. Growth lines weak, irregularly spaced. The width about two-fifth of the height. Aperture ovate about one-third of the height. Outer lip thin. Columellar lip smooth, parietal callus not thicken.

Remarks: The shell outline is similar to that of *Semisulcospira* (*Biwamelania*) *arenicola* distributed on sandy bottoms in the east shore of Lake Biwa. However, it is distinguishable from *S.* (*B.*) *arenicola* by many distinct, prominent spiral carinae on the shell surface. It may be distinguished from an another morphologically similar species, *S.* (*B.*) *shiraishiensis* limited to Okino-shiraishi reef in Lake Biwa by having a distinct spiral carina on shell surface with a sharp apical angle.

This new species corresponds with *S.* (*B.*) sp. 1 of Matsuoka and Nakamura (1981) and *S.* (*B.*) sp. 1 of Matsuoka (1983).

Measurements (*in mm*)*:

	H	W	BWL	AH	AA
TMNH 10530 (Holotype)	27.0	8.3	14.8	7.8	11.5
TMNH 10531	20.6	8.7	13.0	6.6	9.9
MFM110055**	21.4	8.4	14.1	-	11.5

*H = shell height, W = shell width, BWL = body whorl length, AH = aperture height, AA = apical angle.

**Matsuoka and Nakamura, 1981, pl. 41, figs. 9a, b (TN-11)

***Semisulcospira* (*Biwamelania*) *pseudomultigranosa*, nov. sp.**

(Figs. 2.2–2.3)

Type locality: An exposure created by the construction of a housing complex, about 800 m southeast of Ogi-cho, Otsu City, Shiga Prefecture (Loc. C in Fig. 1).

Derivation of name: This species is named from *pseudo-* (Greek, prefix meaning false) and the specific name of *Semisulcospira multigranosa* Boettger.

Material studied: Three specimens. Holotype, TMNH 10532; paratype, TMNH10532a; other specimen, TMNH 10547.

Diagnosis: Shell medium, narrowly conic; spiral cords distinct, eight, axial ribs indistinct. The suture deeply impressed. The basal cords two-three.

Description: Shell medium for this genus, narrowly conic. Spire high turreted, lacking the embryonic and early postembryonic shell; the apical angle about 16.2 degree. Apex eroded, about three whorls remaining. The whorls convex. The suture deeply impressed. Sculpture of spire consisting of many distinct spiral cords, the number of cords on a whorl eight. Basal cords strong, two. Axial ribs indistinct or mostly absent. Growth lines weak, irregularly spaced. The width about two-fifth of the height. Aperture ovate, about two-fifth of the height. Outer lip thin. Columellar lip smooth, parietal callus not thicken.

Remarks: This new species corresponds with *Semisulcospira* (*Biwamelania*) sp. 1 of Matsuoka (1986). The shell outline is similar to that of *S.* (*B.*) *multigranosa*, *S.* (*B.*) *fluvialis* Watanabe and Nishino, and *S.* (*B.*) *decipiens*. This species is distinguishable from *S.* (*B.*) *multigranosa* by having distinct spiral cords on the adult shell surface and by the pronounced ribs on the mid-whorls of the embryonic shell (TMNH 10532a). *Semisulcospira* (*B.*) *decipiens* and *S.* (*B.*) *fluvialis* differ from *S.* (*B.*) *pseudomultigranosa* nov. sp. in the absence of clear spiral cords and their flat-sided whorls.

Measurements (*in mm*):

	H	W	BWL	AH	AA
TMNH10532a (Holotype)	25.7	10.1	17.2	9.4	16.2
TMNH10547	26.8	10.3	14.8	-	-

***Semisulcospira* (*Biwamelania*) *spinulifera*, nov. sp.**

(Figs. 2.4–2.9)

Type locality: Muddy fossiliferous bed about 20 meters below ground, Otsu City, Shiga Prefecture (Loc. F in Fig. 1).

Derivation of name: The specific name composed of Latin "*spinula*" (spine) and from the Latin, "*fer*" (to bear) related to undulatory suture with spinose.

Material studied: Thirty-eight specimens. Holotype, TMNH10534; paratypes, TMNH10533, TMNH10534a, TMNH10535–TMNH10537, LBM0122008709–LBM0122008712; other specimens, TMNH10538, TMNH10546, LBM0122008713–LBM0122008727.

Diagnosis: Shell medium, elongate, conic, and young whorls smooth or weakly sculptured; the whorl side flattened, bearing distinct spiral cords with periodical cusps. The suture distinct, undulate with spinous nodules. The basal cords distinct, two to four in number. Embryonic shell broadly conic, peripheral carina with nodules.

Description: Shell medium for the genus, thick, elongate, conic. Spire high, lacking the embryonic and early postembryonic shell. Apex eroded, the apical angle about 24.1 degree in average. The whorl profile flat-sided, the periphery slightly rounded. The suture shallow, slightly impressed, undulate. Spiral cords with spinose nodules on

the spire distinct, four to six crossed by axial ribs, and the nodules on suprasuture prominent. Younger whorls, smooth, weakly sculptured, remaining spinose cusps on the spiral cords near the suture. The basal cords strong, two to four. The axial ribs weak to moderately strong, 18 to 24 in number. The growth lines often distinct near the aperture, but invisible at the middle to top of spire. The width about two-fifth of the height. The aperture rather narrow, ovate, less than two-fifth of the height. Columellar lip smooth and parietal callus not thicken.

Remarks: This species corresponds to *Semisulcospira* (*Biwamelania*) sp. 2 of Matsuoka (1986). The shell outline of the new species resembles that of *S.* (*B.*) *habei,* but is distinguishable from *S.* (*B.*) *habei* by having fewer number of spiral cords with spinose nodules. The undulated suture and spinose spiral cords are also the distinct characters in this new species. The shape of embryonic shells (TMNH10534a, TMNH 10536a) is relatively similar to that of *S. kurodai* Kajiyama and Habe, 1961 with respect to lirae on the sutural ramp and peripheral nodules, but the nodules are much pronounced in the new species. Fossil embryonic shell of *Semisulcospira* from the Hiraen Clays (Yasuno, 1980; fig. 10; MFM111170) is identical to the embryos of the new species.

Measurements (*in mm*):

	H	W	BWL	AH	AA
TMNH10533 (Paratype)	27.7	12.2	19.3	10.8	25.2
LBM0122008723	22.6	10.1	15.0	8.9	25.2
LBM0122008724	25.3	11.2	15.7	8.8	26.9
LBM0122008725	26.4	12.1	19.2	10.5	22.7
TMNH10536 (Paratype)	25.4	11.3	16.5	10.2	21.8
LBM0122008726	22.2	11.1	15.3	9.1	26.4
LBM0122008727	28.5	11.9	18.5	10.6	23.0
TMNH10538	21.4	10.1	15.4	9.4	27.5
TMNH10546	21.7	9.7	14.5	9.6	32.2
TMNH10535 (Paratype)	25.3	11.8	17.0	9.3	20.1
LBM0122008709 (Paratype)	25.9	11.1	16.7	9.0	23.2
TMNH10534 (Holotype)	25.6	10.9	15.7	8.9	21.6
LBM0122008711 (Paratype)	26.2	10.8	15.8	9.3	22.2
LBM0122008712 (Paratype)	22.0	10.7	15.0	8.2	25.6
LBM0122008713	28.1	11.4	17.5	9.4	14.9
TMNH10537 (Paratype)	28.0	13.1	19.3	10.0	21.7
LBM0122008714	26.9	12.3	18.7	9.5	18.3
LBM0122008715	21.9	11.4	15.9	8.9	24.5
LBM0122008716	18.8	9.5	13.7	7.3	25.2
LBM0122008717	22.7	9.7	14.1	8.1	26.5
LBM0122008718	20.3	9.3	13.0	7.3	16.6
LBM0122008719	16.9	8.5	11.9	7.1	33.4
LBM0122008720	14.9	7.2	10.1	6.2	25.2
LBM0122008721	11.8	6.7	8.1	4.0	27.5
LBM0122008710 (Paratype)	17.9	8.9	11.4	6.6	28.3
LBM0122008722	13.6	7.3	10.1	6.2	22.1

***Semisulcospira* (*Biwamelania*) *kokubuensis* nov. sp.**

(Figs. 2.10–2.13)

Type locality: Muddy fossiliferous bed about 20 meters below ground, Kokubu, Otsu City, Shiga Prefecture (Loc. F in Fig. 1).

Derivation of name: This species is formed after the name of place, Kokubu from which the type specimens were collected.

Material studied: Twenty-two specimens. Holotype, TMNH10543; paratypes, TMNH10543a, b, TMNH10544, TMNH10545, LBM0122008732, LBM0122008733; other specimens, LBM0122008734–LBM0122008733.

Diagnosis: Shell small, elongate, conic, with five whorls; fine nodules on the whorls. The basal cords distinct, three to five in number. Embryonic shell elongated with pronounced axial ribs.

Description: Shell size small for the genus, moderately thick, ovate, conical. Spire moderately elevated and always lacking the embryonic and early postembryonic shell; the apical angle about 27.5 degree. The spire consisting of about four whorls, increased irregularly in size. The whorl slightly convex. The suture shallow, slightly impressed, not undulate. Spiral cords on the spire relatively distinct and enlarged into prominent nodules at their intersecting with the axial ribs. The spiral cords five to six, the subsutural cord with narrowly sutural ramp. Axial ribs on the penultimate whorl 23 to 35, often indistinct, almost equal to the width of intercostal space. The width about one-half of the height. Aperture ovate, less than one-third of the height. The basal cords strong, three to five. Columellar lip smooth, parietal callus not thicken.

Remarks: The outline of the adult shell of the new species does not resemble any extant and fossil species of *Biwamelania*. The finely nodulated structure on the surface of the whorls is similar to that of *Semisulcospira* (*Biwamelania*) *multigranosa*. However, the nodules of *S.* (*B.*) *multigranosa* are larger and more distinct compared with the new species.

The embryonic shells (TMNH10543a, b) resemble those of *S.* (*B.*) *pusilla* nov. sp., *S.* (*B.*) *takeshimensis* and *S.* (*B.*) *shiraishiensis*, by having an elongated embryonic shell with distinct ribs with two nodes.

Measurements (*in mm*):

	H	W	BWL	AH	AA
LBM0122008734	20.9	9.7	15.6	8.3	35.3
LBM0122008735	19.7	8.7	14.5	8.7	26.4
LBM0122008736	14.2	7.5	11.9	6.8	27.3
TMNH10545	18.5	9.1	14.6	8.4	34.1
(Paratype)					
LBM0122008737	20.7	9.2	14.7	8.4	27.7
LBM0122008738	17.7	8.5	12.4	7.1	24.2
LBM0122008732	19.9	9.1	13.5	7.8	26.1
(Paratype)					
LBM0122008739	22.4	9.4	14.1	7.6	22.3
LBM0122008740	25.2	10.8	16.1	9.1	21.8
TMNH10543	21.4	11.2	15.6	8.1	27.5
(Holotype)					
LBM0122008741	17.7	8.0	12.8	6.8	28.6
TMNH10544	22.1	11.0	16.6	9.0	30.5
(Paratype)					
LBM0122008742	18.5	9.1	13.7	7.2	23.9
LBM0122008733	20.0	9.1	14.2	8.0	29.3
(Paratype 4)					

Semisulcospira (*Biwamelania*) *pusilla*, nov. sp.

(Figs. 2.14–2.17)

Type locality: Muddy fossiliferous bed about 20 meters below ground, Kokubu, Otsu City, Shiga Prefecture (Loc. F in Fig. 1).

Derivation of name: The specific name is from the Latin "*pusill*" (very small, week).

Material studied: Twenty-one specimens. Holotype, TMNH10540; paratypes, TMNH10540a, b, TMNH10541, TMNH10542, LBM0122008723, LBM0122008724; other specimens, TMNH10539, LBM0122008725–LBM0122008731.

Diagnosis: Shell small, narrowly conic; spiral lirae distinct, six to eight; axial ribs relatively distinct. The suture distinct impressed. The basal cords two to four. Embryonic shell ovate, conic, pronounced axial ribs with distinct nodes.

Description: *Adults*-shell small for this genus, relatively thin, narrow, conic. Spire high turreted, lacking the embryonic and early postembryonic shell; the apical angle about 16.0 degree in average. Apex eroded, about three whorls remaining. The whorl profile flat-sided; the periphery weekly convex. The suture distinct impressed, not undulate. Sculpture of spire consisting of many distinct spiral lirae with regularly beaded, the number of lirae on a whorl six to ten. The subsutural spiral lirae more closely spaced than the others. Basal cords strong, two to four. Axial ribs on the penultimate whorl 25 to 40. Growth lines weak, irregularly spaced. The width about two-fifth of the height. Aperture ovate, about one-third of the height. Outer lip thin. Columellar lip smooth, parietal callus not thicken.

Remarks: This species was not listed in Matsuoka and Nakamura (1981), but was recognized as *Semisulcospira* (*Biwamelania*) sp. 3 in Matsuoka (1986). The outline of the adult shell of the new species resembles that of *S.* (*B.*) *fluvialis*, but it is distinguishable from *S.* (*B.*) *fluvialis* by distinct spiral lirae and axial ribs. *S.* (*B.*) *multigranosa* also resembles *S.* (*B.*) *pusilla* nov. sp., but the extant species is readily distinguished by coarse nodes and fewer axial ribs. The finely nodulated structure on whorls is similar to that of *S.* (*B.*) *kokubuensis* nov. sp. However, the outline of the new species is clearly slender compared with this new species, but differs in having slender outline.

The embryonic shells (TMNH10540a, b) resemble those of *S.* (*B.*) *takeshimensis* and *S.* (*B.*) *shiraishiensis* in respect to elongate shell outline with distinct axial ribs. However, the embryonic shells of the new species have fewer axial ribs than those of *S.* (*B.*) *takeshimensis* and *S.* (*B.*) *shiraishiensis*.

Measurements (*in mm*):

	H	W	BWL	AH	AA
LBM0122008725	21.5	8.6	15.0	9.0	21.0
LBM0122008726	21.3	8.3	13.6	7.8	15.7
TMNH10542	20.8	7.6	12.4	5.4	13.7
(Paratype 2)	25.3	11.2	15.7	8.8	26.9
TMNH10539	18.2	7.2	10.9	6.3	18.9
LBM0122008727	17.4	7.4	11.1	5.8	17.5
TMNH10540	20.2	7.8	12.1	6.6	16.9
(Holotype)	22.2	11.1	15.3	9.1	26.4
LBM0122008728	16.1	6.8	9.6	5.9	16.7
LBM0122008729	15.4	6.4	9.7	4.7	13.5
LBM0122008723	19.1	7.6	11.6	6.2	14.2
(Paratype 1)	25.3	11.8	17.0	9.3	20.1
LBM0122008730	16.7	6.5	9.0	4.9	14.3
LBM0122008724	19.0	7.3	11.1	6.2	14.1
(Paratype 4)					
LBM0122008731	18.4	7.8	10.6	6.2	13.1
TMNH10541	19.8	9.3	14.1	7.8	17.8
(Paratype 3)					

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