Oligocene pteropods (Gastropoda: Thecosomata) from the Kishima Formation, Saga Prefecture, southwest Japan

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ABSTRACT

Five species in two genera of pteropods, Limacina conica (Koenen, 1892), L. hospes Rolle, 1861, L. karasawai new species, Limacina sp. and Creseis kishimaensis new species, are described from the Oligocene Kishima Formation of Saga Prefecture, northwestern Kyushu, southwest Japan. These species constitute the first Oligocene pteropod record from Japan. The pteropod fauna of the Kishima Formation is characterized by the predominate occurrence of the genus Limacina. The Oligocene pteropod fauna from Japan is briefly discussed.

Key words: Pteropoda, new species, biostratigraphy, Oligocene, Japan.

RESUMEN

Se describen cinco especies de dos géneros de pterópodos, Limacina conica (Koenen, 1892), L. hospes Rolle, 1861, L. karasawai nueva especie, Limacina sp. y Creseis kishimaensis nueva especie, correspondientes a la Formación Kishima del Oligoceno en la Prefectura de Saga, al noroeste de Kyushu, suroeste de Japón. Estas especies representan el primer registro de pterópodos del Oligoceno de Japón. La fauna de pterópodos de la Formación Kishima se caracteriza por la presencia predominante del género Limacina. La fauna de pterópodos del Oligoceno de Japón es discutida brevemente.

Palabras clave: Pteropoda, nuevas especies, bioestratigrafía, Oligoceno, Japón.

INTRODUCTION

Paleogene Pteropoda have been well reported from the Gulf and eastern coasts of North America, England, France, the Netherlands, Germany, Austria, Hungary and others through the north Atlantic to the Mediterranean Sea regions (*e.g.*, Cahuzac and Janssen, 2010; Curry, 1965, 1982; Hodgkinson *et al.*, 1992; Janssen, 1989a; Zorn, 1991). However, there have been only two fossil records of Paleogene pteropods from the Northwest Pacific region (Ando *et al.*, 2009; Chen and Huang, 1990). Ando *et al.* (2009) reported nine species from the Middle to Upper Eocene rocks in the Amakusa-Shimoshima, northwestern Kyushu, Japan, and Chen and Huang (1990) described two species from the Oligocene in Taiwan.

During field work performed between 2008 and 2010, I collected more than 100 pteropod specimens from the Oligocene Kishima Formation, northwestern Kyushu,

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southwest Japan. These fossils constitute the first Oligocene pteropod record from Japan. The purpose of this paper is to describe pteropods including two new species and to discuss its faunal composition.

The specimens described in this paper are deposited in the Mizunami Fossil Museum (MFM200001–200021). The images of specimens were taken by a scanning electron microscope (Miniscope TM-1000: Hitachi High-Technologies Co.) at the Nagoya University Museum.

LOCALITY AND GEOLOGICAL SETTING

The specimens described here were collected from the Kishima Formation (Nagao, 1927) in Kitahata-Shimohirano, Karatsu City, Saga Prefecture, Japan (Figure 1). Details of localities are as follows:

Loc. 1. Riverbank of the Tanaka river, Kitahata-Shimohirano, Karatsu City, Saga Prefecture (Lat 33°22’54”N, Long 129°56’3”E). Uppermost part of the Kishima Formation.

Loc. 2. Riverbed of a branch of the Tanaka river, Kitahata-Shimohirano, Karatsu City, Saga Prefecture (Lat 33°22’50”N, Long 129°55’45”E). Uppermost part of the Kishima Formation.

The formation consists of sandy mudstone, mudstone and sandstone, and contain shallow-marine mollusks such as *Turritella karatsuensis*, *Nucula hizenensis*, *Pitar matsuraensis* (Inoue, 1972), decapods (Karasawa, 1993; Karasawa and Fudouji, 2000), ostracods (Yamaguchi *et al.*, 2006), and calcareous nannoplanktons (Okada, 1992). The fossil-bearing horizons are in the uppermost part of the Kishima Formation. The specimens were collected in the sandy mudstone of this formation. All of them were included within calcareous nodules. All specimens lack shells and are represented by their internal molds. Okada (1992) showed that the geologic age of the uppermost part of the Kishima Formation is the earliest early Oligocene (CP16a: Okada and Bukry, 1980).

SYSTEMATIC PALEONTOLOGY

Order Thecosomata Blainville, 1824
Suborder Euthecosomata Meisenheimer, 1905
Family Limacinidae Gray, 1847
Genus *Limacina* Bosc, 1817

***Limacina conica* (Koenen, 1892)**
Figures 2.1 - 2.3

Spirialis conica Koenen, 1892, p. 994, pl. 62, figs. 5, 6.
Spiratella (*Altaspiratella*) *conica* (Koenen), Korobkov, 1966, p. 80.
Limacina conica (Koenen), Gürs and Janssen, 2004, p. 201.

Description of the specimens. Shell moderate in size for genus *Limacina* (average: height 1.6 mm, width 1.0 mm), sinistral, highly conical, with 4 to 4.5 whorls. Shell height about 1.5 times as high as width. Whorls increasing slowly

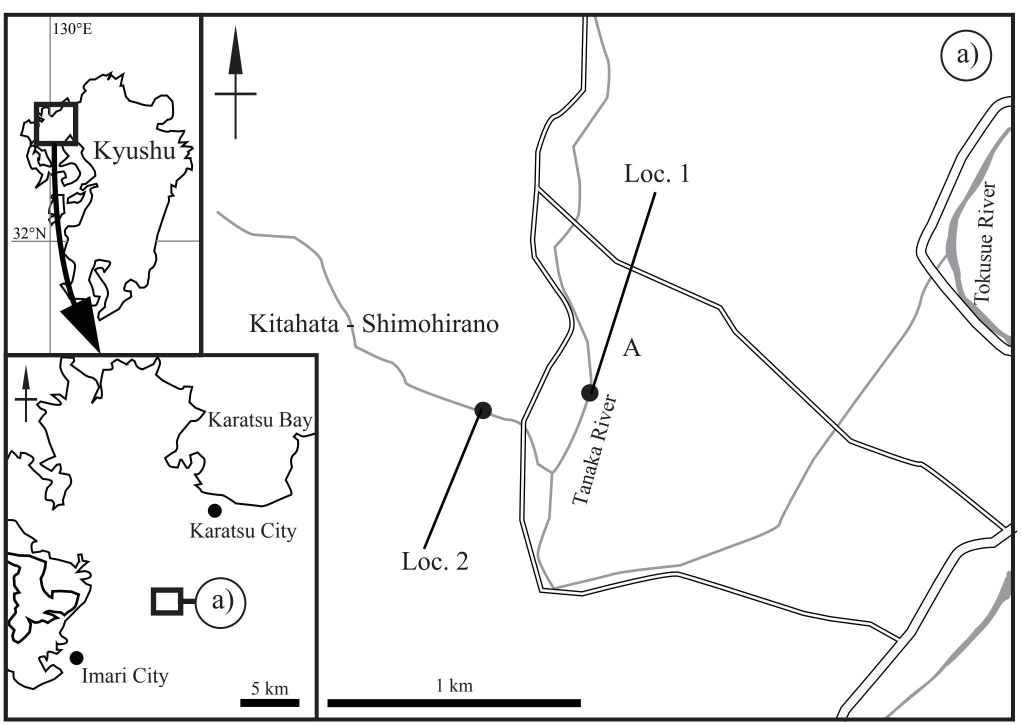

Figure 1. Map showing the collection localities in the Karatsu area.

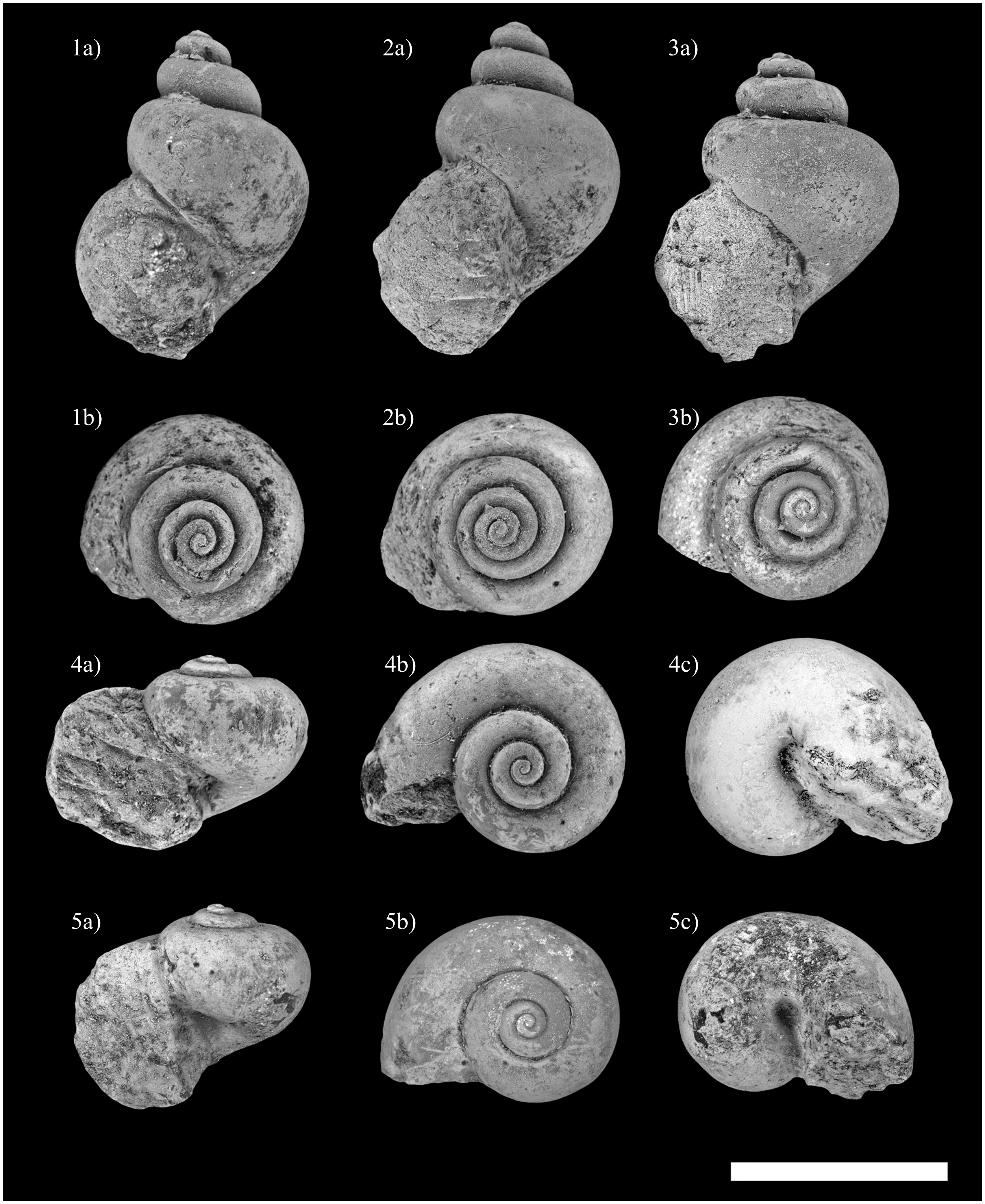

Figure 2. 1-3: *Limacina conica* (Koenen, 1892); 1: MFM200001, Loc. 1, 1a: apertural view; 1b: upper view; 2: MFM200002, Loc. 2, 2a: apertural view; 2b: upper view; 3: MFM200003, Loc. 2, 3a: apertural view; 3b: upper view. 4, 5: *Limacina hospes* Rolle, 1861; 4: MFM200006, Loc. 1, 4a: apertural view; 4b: upper view; 4c: umbilical view; 5: MFM200007, Loc. 2, 5a: apertural view; 5b: upper view; 5c: umbilical view. Scale bar indicates 1.0 mm.

and gradually in diameter to toward aperture. Spire high, average apical angle 60°. Suture deep. Apex small, rounded. Umbilicus very narrow. Aperture slightly oblique, rounded, higher than wide.

Measurements. MFM200001, height 1.6 mm, width 1.1 mm, H/W ratio 1.5, number of whorls 4.5, apical angle 64°. MFM200002, height 1.7 mm, width 1.1 mm, H/W ratio 1.5, number of whorls 4.5, apical angle 60°. MFM200003, height 1.6 mm, width 1.0 mm, H/W ratio 1.6 number of whorls 4, apical angle 66°. MFM200004, height 1.7 mm, width 1.0

mm, H/W ratio 1.7, number of whorls 4.5, apical angle 56°. MFM200005, height 1.5 mm, width 1.0 mm, H/W ratio 1.5, number of whorls 4, apical angle 58°.

Material examined. MFM200001–MFM200005, and other referred 30 specimens.

Occurrence. Loc. 1 and Loc. 2. Uppermost part of the Kishima Formation (earliest early Oligocene).

Remarks. The specimens of the Kishima Formation are identified with *Limacina conica* described from the Lower Oligocene in Germany (Koenen, 1892), because they have a high spire and gently increasing whorls. This species is most similar to *Limacina amudariensis* (Korobkov, 1966), an another Oligocene species from southwest Russia, but differs in having a more slender shell (H/W ratio of holotype is 1.3; Korobkov, 1966).

Geographic distribution. Germany (Koenen, 1892), Tajikistan (Korobkov, 1966).

***Limacina hospes* Rolle, 1861**
Figures 2.4 - 2.5

Limacina hospes Rolle, 1861, p. 205, pl. 1, fig. 1.
Spirialis hospes (Rolle), Kittl, 1886, p. 69, pl. 2, fig. 39; Gheorghian *et al.*, 1967, p. 8, pl. 1, fig. 1a–c.
Limacina hospes Rolle, Janssen, 1984, p. 69, pl. 2, fig. 1; Janssen, 1990, p. 84, text-figs. 1–6; Zorn, 1991, p. 99, pl. 2, figs. 1–7, pl. 10, fig. 5, pl. 11, fig. 1.
Heliconoides hospes (Rolle), Gürs and Janssen, 2004, p. 201; Cahuzac and Janssen, 2010, p. 31, pl. 7, figs. 1–9.

Description of the specimens. Shell moderate in size for genus *Limacina* (average: height 1.0 mm, width 1.2 mm), sinistral, low conical, with about 3.5 whorls. Shell height about 0.8 its width. Shell width increasing in size slowly at the first two whorls, then more rapidly later whorls. Margin of whorls rounded. Suture deep. Spire relatively low, apical angle about 130°. Apex small, rounded. Umbilicus narrow, 5% its width. Aperture large, oval, about as high as wide.

Measurements. MFM200006, height 1.1 mm, width 1.4 mm, H/W ratio 0.8, number of whorls 4, apical angle 130°. MFM200007, height 1.1 mm, width 1.2 mm, H/W ratio 0.9, number of whorls 3.5, apical angle 132°. MFM200008, height 0.9 mm, width 1.1 mm, H/W ratio 0.8 number of whorls 4, apical angle 135°. MFM200009, height 1.0 mm, width 1.3 mm, H/W ratio 0.8, number of whorls 3, apical angle 132°. MFM200010, height 0.8 mm, width 1.0 mm, H/W ratio 0.8, number of whorls 3, apical angle 132°.

Material examined. MFM200006–MFM200010, and other referred 83 specimens.

Occurrence. Loc. 1 and Loc. 2. Uppermost part of the Kishima Formation (earliest early Oligocene).

Remarks. The specimens of the Kishima Formation are identified with *Limacina hospes*, firstly described from the Lower Oligocene in Germany (Rolle, 1861), by its outline of shell and having a low spire and a narrow umbilicus. This species has been known from early to late Oligocene sediments in Denmark, Germany, other localities around the North Sea Basin, Hungary and southwest France (*e.g.*, Gürs and Janssen, 2004; Cahuzac and Janssen, 2010). The Kishima specimens are similar to *Limacina curryi* Janssen, 1989, from the Upper Oligocene in Australia by low spire and the H/W ratio of the shell. However, *L. curryi* has a wider umbilicus (about 15% of width; Janssen, 1989b). They are also similar to *Limacina dilatata* (Koenen, 1892) from the Oligocene in Germany, but differ in having a lower spire.

Geographic distribution. Austria (Zorn, 1991), Southwest France (Cahuzac and Janssen, 2010), Belgium (Janssen, 1989a), Denmark (Janssen, 1990), Germany (*e.g.*, Rolle, 1861), Hungary (Bohn-Havas *et al.* 2004).

***Limacina karasawai* new species**
Figures 3.1 - 3.2

Diagnosis. Shell moderate, sinistral, semicercular. Shell height 0.6 to 0.8 times as high as width. Spire weakly elevated, whorl increasing gradually. Aperture rounded, higher than wide. Umbilicus wide.

Etymology. In honor of Dr. Hiroaki Karasawa.

Description. Shell moderate in *Limacina* (holotype: height 0.9 mm, width 1.3 mm), sinistrally coiled in a nearly horizontal plane, with about 4 whorls. Shell height 0.7 to 0.8 times as high as width. Shell width gently increasing in size slowly at the first 2.5 whorls, later whorls then more gently increasing in width. Body whorl large, slightly shouldered. Suture strongly impressed. Spire weakly elevated with an apical angle 160° (holotype). Apex small, slightly rounded. Umbilicus deep, wide, 20% as wide as width. Aperture roughly rounded, semispherical, higher than wide.

Measurements. MFM200011, height 0.9 mm, width 1.3 mm, H/W ratio 0.7, number of whorls 4.5, apical angle 160°. MFM200012, height 1.0 mm, width 1.2 mm, H/W ratio 0.8, number of whorls 4, apical angle 158°. MFM200013, height 0.8 mm, width 1.2 mm, H/W ratio 0.7 number of whorls 4, apical angle 155°.

Material examined. MFM200011 (holotype), MFM200012 (paratype), MFM200013 and other referred 1 specimen.

Occurrence. Loc. 2. Uppermost part of the Kishima Formation (earliest early Oligocene).

Remarks. *Limacina karasawai* new species is most similar to *Limacina augustana* (Gardner, 1951) from the Lower Eocene in USA by its outline and by having a wide umbilicus. However, the new species is smaller than *Limacina augustana* (maximum width is 3 mm; Gardner, 1951), even though it is not as high in relation to its width. The new species is also similar to *Limacina plana* (Tembrock, 1964) from the Oligocene in Germany by having a wide umbilicus, but differs in having a smaller H/W ratio (H/W ratio of holotype is 0.5; Tembrock, 1964). This new species resembles *Limacina atypica* (Laws, 1944) from the Upper Oligocene in Australia. However, *Limacina atypica* has a distinct constriction just behind the apertural margin

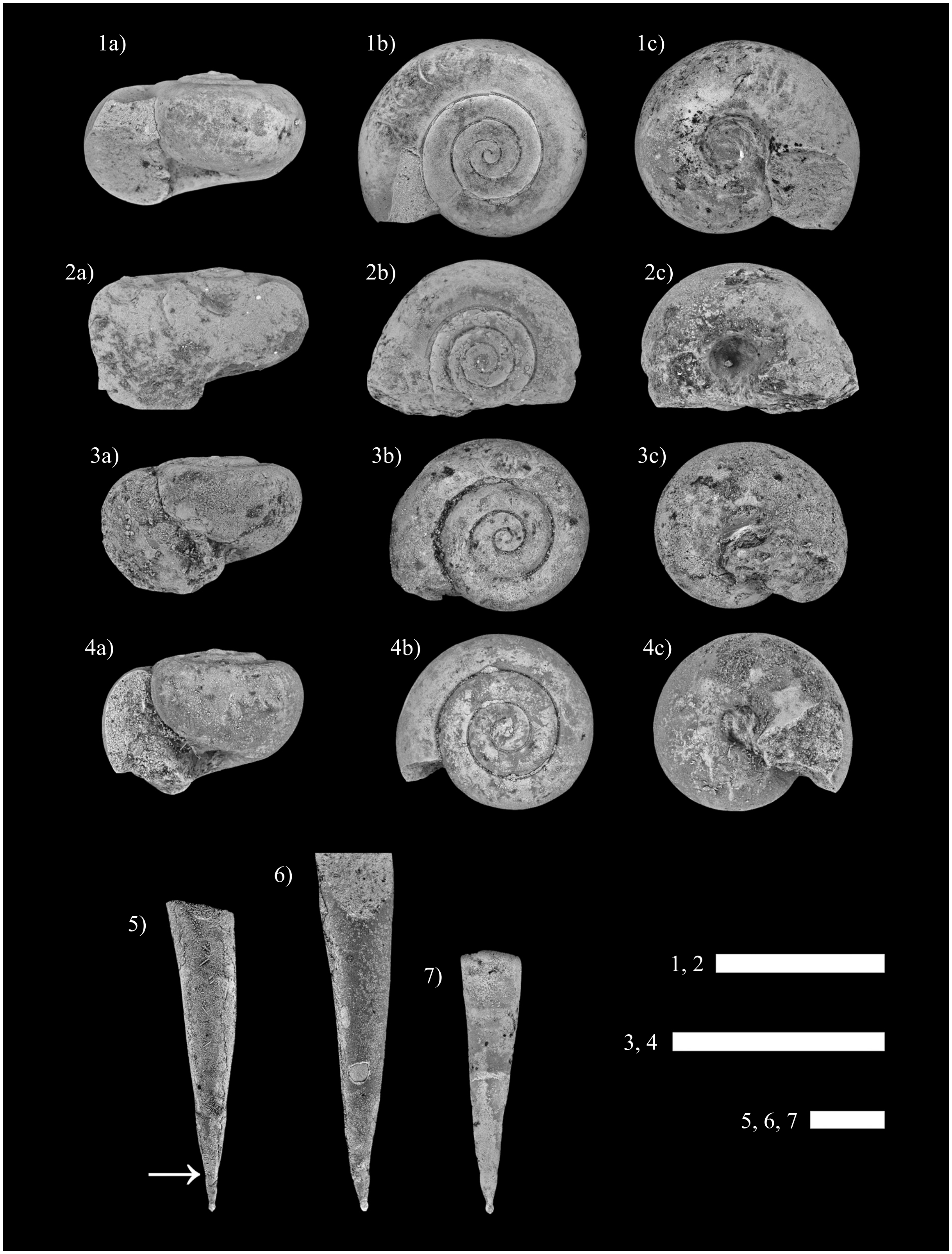

Figure 3. 1, 2: *Limacina karasawai* new species. 1: Holotype, MFM200011, Loc. 2, 1a: apertural view; 1b: upper view; 1c; umbilical view. 2: Paratype, MFM200012, Loc. 2; 2a: apertural view; 2b: upper view. 3, 4: *Limacina* sp.; 3: MFM200014, Loc. 1, 3a: apertural view; 3b: upper view; 3c: umbilical view; 4: MFM200015, Loc. 1, 4a: apertural view; 4b: upper view; 4c: umbilical view. 5-7: *Creseis kishimaensis* new species; 5: Holotype, MFM200017, Loc. 2, arrow shows a constriction; 6: Paratype, MFM200018, Loc. 2; 7: Paratype, MFM200019, Loc. 2. Scale bar indicates 1.0 mm.

which *L. karasawai* new species lacks. The new species also resembles *Limacina pseudoumbilicata* (Korobkov, 1966) from the Oligocene in Germany, but differs in having a smaller shell (about 1/3 of *L. pseudoumbilicata*) and a more rounded shoulder.

***Limacina* sp.**
Figures 3.3 - 3.4

Description. Shell small in genus *Limacina* (average: height 0.7 mm, width 0.9 mm), sinistral coiled, with about 3 whorls. Shell height 0.8 maximum width. Whorls increasing regularly. Spire relatively low, apical angle 145° to 150°. Suture impressed. Apex small, moderately inflated. Umbilicus width 5 to 10% maximum width. Aperture narrow-oval, higher than wide.
Measurements. MFM200014, height 0.7 mm, width 0.9 mm, H/W ratio 0.8, number of whorls 3, apical angle 150°. MFM200015, height 0.6 mm, width 0.8 mm, H/W ratio 0.8, number of whorls 3, apical angle 145°. MFM200016, height 0.6 mm, width 0.8 mm, H/W ratio 0.8 number of whorls 3, apical angle 148°.
Material examined. MFM200014–MFM200016 and other referred 8 specimens.
Occurrence. Loc. 1 and Loc. 2. Uppermost part of the Kishima Formation (earliest early Oligocene).
Remarks. *Limacina* sp. appears to be closely related to *Limacina lini* Chen and Huang, 1990, from the Oligocene in Taiwan. In *Limacina* sp. the shell width of MFM200014 is 0.9 mm and this species has a low spire, while in *L. lini* the maximum shell width is less than 0.4 mm and the spire cannot be elevated. This species resembles *Limacina umbilicata* (Bornemann, 1855), from the Oligocene in Germany. However, *Limacina umbilicata* differs from this species in having a well developed shoulder with body whorl in side view. *Limacina* sp. is also closely related to *L. karasawai* by its outline and some characters. Therefore, this species is possibly the juvenile specimens of *Limacina karasawai*.

Family Cavoliniidae Fisher, 1883
Genus *Creseis* Rang, 1828

***Creseis kishimaensis* new species**
Figures 3.5 - 3.7

Diagnosis. Shell conical, slender, slightly curved. Surface of internal mold smooth without ornamentation. Apical angle 10° to 14°. Protoconch clearly separated from teleoconch with a constriction. Embryonic shell conical slightly rounded.
Etymology. The specific name refers to the Kishima Formation from which this species was collected.
Description. Shell conical, slender, elongately in cross section, slightly curved posteriorly. Surface of internal mold smooth, with no ornamentation and growth lines. Length reaching 5 mm. Maximum shell width 0.8 mm (holotype). Shell width increasing gently just after embryonic shell, then more gently toward aperture. Apical angle 10° to 14° (see Figure 4). Protoconch clearly separated from teleoconch by a well-defined constriction situated at 0.4 mm from the posterior end (holotype). Embryonic shell elongate, bearing slightly rounded tip. Aperture not reconstructed.

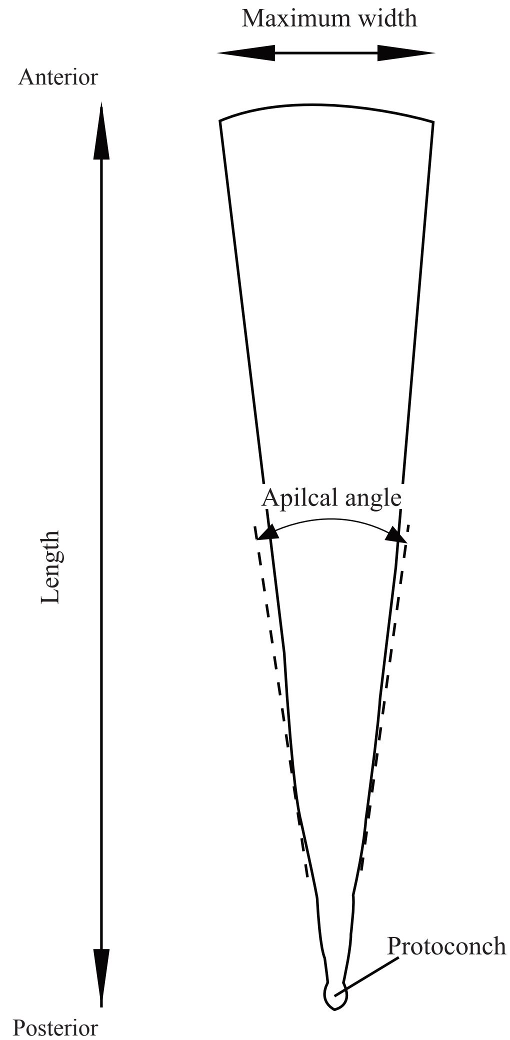

Figure 4. Characters measured on *Creseis*.

Measurements. MFM200017, length 4.2 mm, maximum width 0.8 mm, apical angle 12°. MFM200018, length 5.2 mm, maximum width 0.9 mm, apical angle 10°. MFM200019, length 3.6 mm, maximum width 0.8 mm, apical angle 14°. MFM200020, length 2.9 mm, width 0.6 mm, apical angle 12°. MFM200021, length 5.1 mm, maximum width 0.7 mm, apical angle 10°.
Material examined. MFM200017 (holotype), MFM200018 (paratype), MFM200019 (paratype) , MFM200020, MFM200021 and other referred 20 specimens.
Occurrence. Loc. 2. Uppermost part of the Kishima Formation (earliest early Oligocene).
Remarks. *Creseis kishimaensis* new species is most similar

to *C. antoni* Cahuzac and Janssen, 2010, from the Lower Oligocene in France. However, the new species differs from *C. antoni* in having a slightly curved shell and a clear constriction situated at 0.4 mm from the posterior end. *Creseis kishimaensis* new species is similar to *C. inaequiconica* Bielokrys, 1997, from the Upper Eocene in Ukraine, but *C. inaequiconica* has a wider apical angle (15° to 19°) and slightly larger shell. Additionally, shell width of *C. inaequiconica* increases more rapidly toward the aperture. The new species resembles *Creseis simplex* (Meyer, 1886) from the Middle to Upper Eocene of USA. However, this new species differs from *C. simplex* by having a wider shell width and a more rounded embryonic shell. This new species also resembles *Creseis cincta* Koenen, 1892. However *Creseis cincta* has annulations on the shell surface.

REMARKS OF THE EARLY OLIGOCENE PTEROPOD FAUNA OF NORTHWESTERN KYUSHU

The pteropods from the uppermost part of the Kishima Formation constitute five species, including *Limacina conica* (Koenen), *L. hospes* Rolle, *L. karasawai* new species, *L.* sp., *Creseis kishimaensis* new species (Table 1). This fauna is characterized by the predominance of *Limacina*. *Limacina hospes* is predominant for the pteropod faunas from the Oligocene of Europe (*e.g.*, Gürs and Janssen, 2004; Cahuzac and Janssen, 2010). This species represents the first record from the Pacific region and the oldest fossil record of the world. Therefore, *Limacina hospes* appears to characterize the pteropod faunas from the Oligocene through the world.

Table 1. List of pteropods from the Kishima Formation.

Species/Localities	Loc. 1	Loc. 2
Limacina conica (Koenen, 1892)	7	28
L. hospes Rolle, 1861	13	75
L. karasawai new species		4
L. sp.	3	8
Creseis kishimaensis new species		23

The pteropod fauna from the Kishima Formation differs from that of the Middle to Upper Eocene Oniike Formation by the specific composition (Figure 5). The pteropod fauna from the Oniike Formation is consituted by six species, do not contains the pteropod species of the Kishima Formation, and is characterized by the predominance of *Limacina canadaensis* (Ando *et al.*, 2009). However, that of the Kishima Formation does not contain *Limacina canadaensis* and other species reported from the Oniike Formation. This suggests that pteropod faunas in northwestern Kyushu had greatly changed between the late Eocene (CP15a) and the earliest early Oligocene (CP16a). The pteropod faunal change of the late Eocene to early Oligocene has been known from the North Sea Basin (Janssen and King, 1988), France (Cahuzac and Janssen, 2010) and the Gulf of

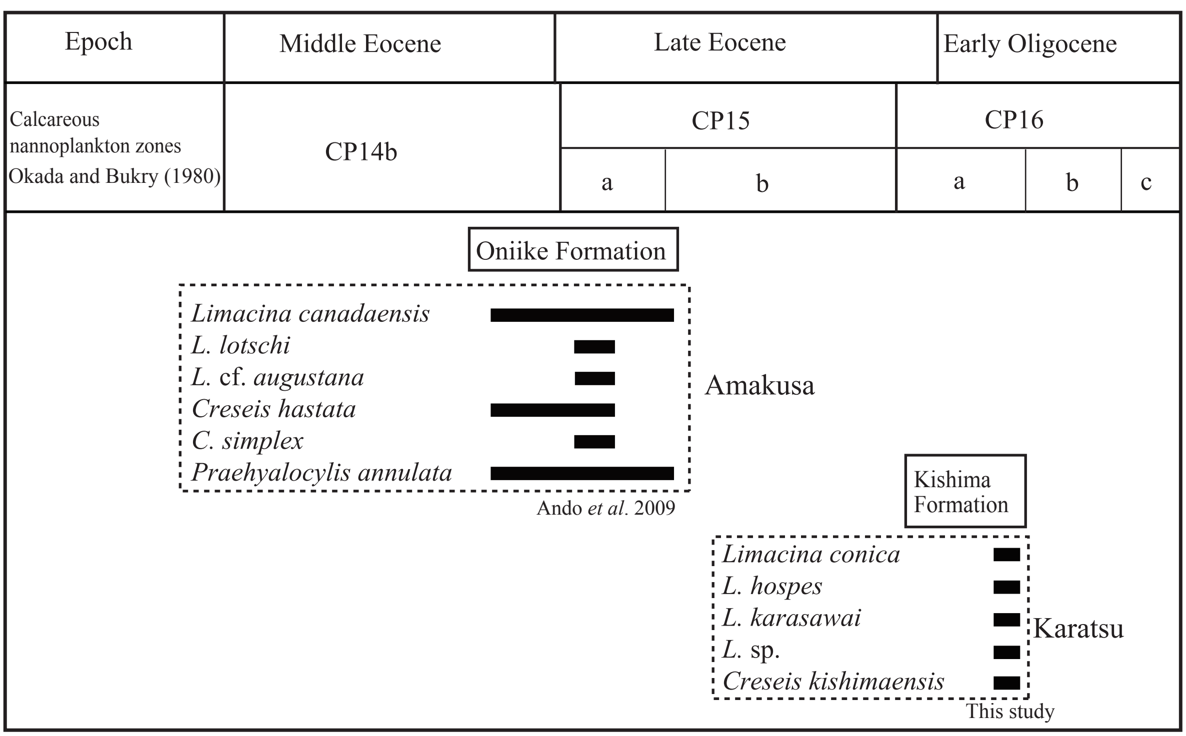

Figure 5. Latest middle Eocene to earliest early Oligocene Pteropod biostratigraphy in northwestern Kyushu correlated to the standard nannoplankton zones (Okada and Bukry, 1980).

Mexico coasts (Hodgkinson *et al.*, 1992). The faunal change between Oniike and Kishima formations is correlated with these changes. Funakawa *et al.* (2005) showed that radiolarians changed at the Eocene/Oligocene boundary in the central equatorial Pacific and suggested that the faunal change was caused by climatic cooling and correlated with global climatic changes (*e.g.*, Zachos *et al.*, 1996). Therefore, the climatic cooling event at the Eocene/Oligocene boundary (*e.g.*, Zachos *et al.*, 1996) appears to be one of the factors that led to the pteropod faunal change between the Oniike and Kishima formations.

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