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Source: Paleontological Research, 25(4) : 375-378

Published By: The Palaeontological Society of Japan

URL: <https://doi.org/10.2517/2021PR006>

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An additional new species of *Turbo* (*Marmarostoma*) (Gastropoda: Turbinidae) from the middle Miocene of the Izu Peninsula, central Japan

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Received May 2, 2020; Revised manuscript accepted July 27, 2020

Abstract. The turbinid gastropod *Turbo* (*Marmarostoma*) is common in the limestone bodies within the middle Miocene Sakurada and Kadono formations (Yugashima Group) on the Izu Peninsula, central Japan. The limestone bodies were originally deposited under a low-latitude, tropical climate in the northeastern Philippine Sea and then drifted northwards on the Philippine Sea Plate. This paper describes an additional species, *Turbo* (*Marmarostoma*) *ishidai* sp. nov., from the Ena Limestone on the south-western Izu Peninsula. This new species is characterized by its large shell size and shell form similar to the modern Australian endemic species *Turbo* (*Marmarostoma*) *cepoides* Smith, 1880, but differs in having thick tuberculate spiral cords on the shell surface of earlier teleoconch whorls instead of the smooth and broad spiral cords on and around the angled shoulder. The addition of this new species further highlights the presence of a biodiversity hotspot of this gastropod group in the northeastern Philippines Sea during the middle Miocene.

Keywords: central Japan, Ena Limestone, Sakurada Formation, Izu Peninsula, middle Miocene, *Turbo* (*Marmarostoma*) *ishidai* sp. nov.

Introduction

Limestone bodies within the middle Miocene Kadono and Sakurada formations (Yugashima Group) in the Izu Peninsula area and the middle Miocene Megami Formation in the Sagara area, central Japan contain fossil corals, larger foraminifers, molluscs and calcareous algae indicative of a tropical shallow sea origin (Nishiwada, 1894; Ishijima, 1968; Kase and Katayama, 1981; Ozawa *et al.*, 1995; Tomida and Kadota, 2012a, b, 2014; Tomida and Hosoda, 2015; Tomida *et al.*, 2013, 2019; Kase *et al.*, 2020). These limestone bodies were uplifted to become part of volcanic islands on the Izu-Ogasawara Arc located in a low-latitude, tropical domain in the northeastern Philippine Sea during the middle Miocene, and then drifted to the present position due to the northward movement of the Philippine Sea Plate (Hirooka *et al.*, 1985; Niitsuma and Koyama, 2006). Although this hypothesis is still controversial, it is thought that the limestone body (Megami Limestone) in the Sagara area was also deposited on a seamount somewhere in the northeastern Philip-

pine Sea (Ozawa *et al.*, 1995). The marine fossil assemblages from these limestone bodies provide a glimpse of poorly recorded tropical marine biodiversity in the northeastern Philippine Sea during the Miocene.

Previous studies have recorded seven species of the turbinid gastropod genus *Turbo*, five from the Izu Peninsula and two from the Sagara area (Nishiwada, 1894; Tomida and Kadota, 2012b, 2014; Kase *et al.*, 2020). Tomida and Kadota (2014) and Kase *et al.* (2020) have demonstrated that *Turbo* (*Marmarostoma*) was more diverse in the northeastern Philippine Sea during the middle Miocene than it is today. Modern species of *Turbo* (*Marmarostoma*) exhibit the highest species richness in the Indo–West Pacific (or the Indo–Australian Archipelago) region delimited by the Philippine and Indonesian archipelagos and Papua New Guinea (Williams and Duda, 2008). Kase *et al.* (2020) further suggested that, during the middle Miocene, the diversity of this subgenus was higher in the northeastern Philippine Sea than in the central part of the Indo–West Pacific area.

In this study, an additional species of *Turbo* (*Marma-*

rostoma) is described from a middle Miocene limestone body on the Izu Peninsula. The occurrence of a new species of *Turbo* (*Marmarostoma*) reported herein further reinforces the notion that the northeastern Philippine Sea represented a biodiversity hotspot for *Turbo* (*Marmarostoma*) during the middle Miocene.

Occurrence and material.—The specimens described in this study were recovered from the Ena Limestone within the middle Miocene Sakurada Formation in the Nishi-izu area of the Izu Peninsula (34°45'42"N, 138°47'9"E; see Tomida and Kadota, 2014, Figure 1; Kase *et al.*, 2020, Figure 1D; Tomida *et al.*, 2019, Figure 1B). The Ena Limestone is composed of two allochthonous limestone blocks: the larger and smaller ones are *ca.* 10 m and 7 m in length and *ca.* 0.8 m and 1.2 m in thickness, respectively. The limestone contains corals, large foraminifers and a number of molluscs indicative of tropical environments (Tomida and Kadota, 2014). Five species of the genus *Turbo* were recorded from the Ena Limestone, and these are *Turbo* (*T.*) *hosodai* Tomida and Kadota, 2014, *Turbo* (*Marmarostoma*) *yoshiharuyabei* Tomida and Kadota, 2014, *T. (M.?) sanoii* Tomida and Kadota, 2014, *T. (M.) matsuzakiensis* Tomida and Kadota, 2012b and *T. (M.) izuensis* Kase *et al.*, 2020. The age of the limestone has been assigned to Okada and Bukry's (1980) calcareous nannofossil zone CN4 (14.9–13.5 Ma) (Okada, 1987). For detailed description and discussion on the collecting site, stratigraphy, lithology, associated fossils and age assignment of the Ena Limestone, see Tomida and Kadota (2012b, 2014), Tomida *et al.* (2017) and Kase *et al.* (2020). Two specimens of the new species were found in this study: the holotype is housed at the National Museum of Nature and Science, Tsukuba (abbreviated as NMNS) and the paratype at the Matsuzaki Geo-park Visitor Center (abbreviated as MGVC).

Taxonomy

Family Turbinidae Rafinesque, 1815

Genus *Turbo* Linnaeus, 1758

Subgenus *Marmarostoma* Swainson, 1829

Type species.—*Turbo chrysostomus* Linnaeus, 1758 (original designation).

***Turbo* (*Marmarostoma*) *ishidai* sp. nov.**

Figure 1A–D

Type-material.—Two specimens; holotype, NMNS PM 28467, shell height 101.2+ mm, shell width 73.7 mm; paratype, MGVC-F0041, shell height 58.5+ mm, shell width 49.8 mm.

Type-locality.—Ena, Matsuzaki-cho, Kamo-gun,

Shizuoka Prefecture.

Diagnosis.—Species similar to *Turbo* (*Marmarostoma*) *cepoides* but with two tuberculate spiral cords on earlier whorls. Spiral cords gradually becoming obscure through growth, and totally absent on last whorl. Shell surface ornamented only with fine spiral lines other than rugose growth lines.

Description of holotype.—Shell large, over 100 mm in height, turbiniform, slightly higher than wide. Spire high, but less than half of shell height. Pleural angle about 70°. Suture impressed. Teleoconch preserving four inflated whorls; preserved spire whorls with two distinct tuberculate spiral cords, one on angled shoulder and other slightly above suture; spiral cords gradually becoming obsolete through growth, totally absent on last whorl. Last whorl well rounded, covered with rugose growth lines and fine and very weak spiral threads probably over shell surface. Base inflated more than upper whorl surface of last whorl. Umbilicus totally closed. Columella smooth, short and evenly curved. Aperture circular. Operculum not known.

Measurements.—Shell height 101.2+ mm, maximum width 87.8 mm, minimum width 73.7 mm, (holotype: NMNS PM28467); Height 58.5+ mm, maximum width 57.6 mm, minimum width 49.8 mm (paratype: MGVC-F0041).

Etymology.—Named after Nobutoshi Ishida in Matsuzaki-cho, for his assistance during the fieldwork.

Discussion.—Although only two, rather poorly preserved specimens are available, they exhibit unique shell characters easily separable from those of other species. The presence of the fine and very weak spiral threads can be seen in some portions of the last whorl in the holotype (Figure 1D), and the presence of the rugose growth lines are easily observable in the paratype (Figure 1A) and on the last half whorl of the holotype (Figure 1C). The presence of these sculpture and growth lines suggest that the shell of *T. (M.) ishidai* sp. nov. may not have been smooth unlike the modern tropical Indo-Pacific species *Turbo* (*Turbo*) *petholatus* Linnaeus, 1758.

Of the five species of *Turbo* recorded from the middle Miocene of the Izu Peninsula, *Turbo* (*Turbo*) *hosodai* Tomida and Kadota, 2014, *Turbo* (*Marmarostoma*?) *sanoii* Tomida and Kadota, 2014 both from the Ena Limestone have a shell height over 100 mm, just like *T. (M.) ishidai* sp. nov. *Turbo* (*T.*) *hosodai* is distinguished from *T. (M.) ishidai* sp. nov. by the rounded whorls throughout the shell growth without any angulation at the shoulder angle and basal periphery, and *T. (M.?) sanoii* is distinguished from *T. (M.) ishidai* sp. nov. by the presence of thick spiral cords (two on the spire whorls and three on the last whorl) throughout the shell growth. *Turbo* (*Marmarostoma*) *yoshiharuyabei* Tomida and Kadota, 2014 from the Ena Limestone has a shell height slightly over

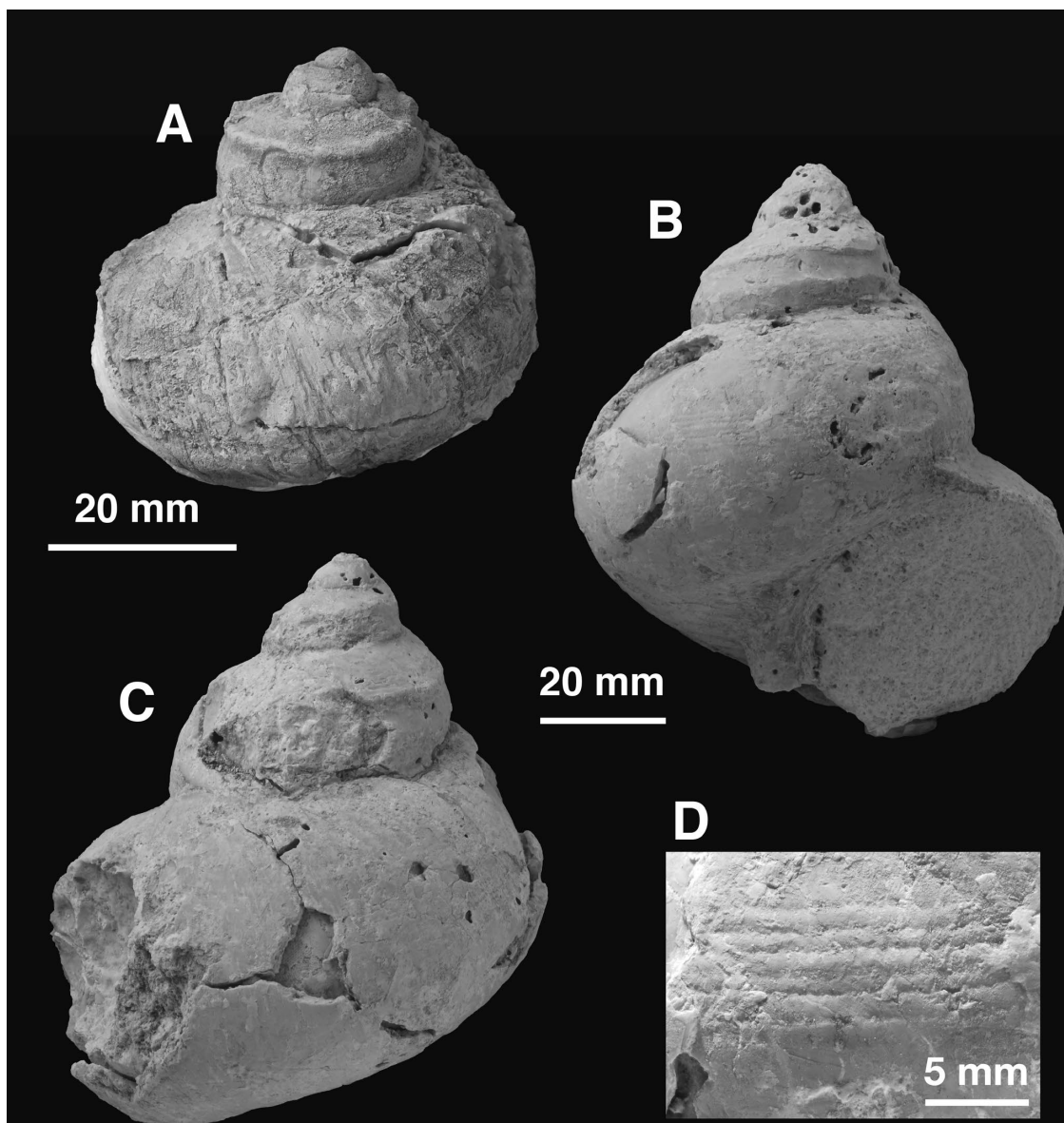


Figure 1. *Turbo (Marmarostoma) ishidai* sp. nov. from the middle Miocene Ena Limestone at Ena, Matsuzaki-cho, Shizuoka Prefecture. **A**, MGVC-F0041 (paratype), apertural view, shell width 49.8 mm, shell height 58.5+ mm; **B–D**, NMNS PM 28467 (holotype); **B**, **C**, apertural and adapertural view; **D**, close-up of **B**, shell surface of the last whorl upper-right of a sinuously elongated groove, showing the presence of fine and very weak spiral cords, shell height 101.2+ mm, shell width 73.7 mm.

95 mm (Tomida *et al.*, 2019). The distinction between the two species is particularly apparent in mature individuals. *Turbo (M.) yoshiharuyabei* is distinct from *T. (M.) ishidaei* sp. nov. in having a wider shell profile, more evenly rounded whorls, and the surface sculpture consisting of thick spiral cords and interstitial spiral threads throughout the shell growth, instead of only indistinct spiral threads in the new species. The other two species of *Turbo*, *Turbo (Marmarostoma) matsuzakiensis* Tomida and Kadota, 2014 and *Turbo (Marmarostoma) izuensis* Kase *et al.*,

2020, from the Miocene of Izu Peninsula have distinct spiral sculptures, or spines on the shoulder angle and basal periphery, characteristic to each species. Therefore, the species described here is the sixth species of the genus *Turbo* from the middle Miocene of the Izu Peninsula.

Turbo (M.) ishidaei sp. nov. resembles *Turbo (Marmarostoma) cepoides* Smith, 1880, a modern species endemic to Lord Howe Island of Australia in the Tasman Sea (Alf and Kreipl, 2003). According to Alf and Kreipl (2003), *T. (M.) cepoides* also reaches a shell height over 100 mm

and has well-inflated smooth whorls. A unique character in *T. (M.) cepoides*, not seen in *Turbo (M.) ishidai* sp. nov., is the presence of broad spiral cords; a strong one on the shoulder angle, one or two on the ramp, and one or none below the shoulder angle (Alf and Kreipl, 2003). In contrast, *T. ishidai* sp. nov. has a prominent angulation at the shoulder angle, which is distinctly noded. In addition to this difference, the shell surface is sculptured with fine spiral cords in *T. (M.) ishidai* sp. nov., while is absent in *T. (M.) cepoides*.

Acknowledgements

We thank R. W. Jordan (Faculty of Science, Yamagata University) for his English improvement of the manuscript, and also K. Inoue (Graduate School of Environmental Studies, Nagoya University, Nagoya) and M. Kadota (Kanagawa Prefectural Museum, Odawara), for their kind assistance during field work. We also thank N. Ishida and E. Hosoda (Izu Fossil Research Club of Matsuzaki-cho, Matsuzaki) who provided the specimens described in this study and kindly assisted us during field-work.

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