化石研究会会誌 Journal of Fossil Research, Vol. 52(1), 33-37(2019)

[Short Report]

Late Miocene specimens of *Aturia* (Cephalopoda: Nautilida) from Utsunomiya, central Japan

Yukito Kurihara*

Introduction

The genus *Aturia* Bronn, 1838 is a Cenozoic fossil nautiloid with a worldwide geographical distribution, appearing in the Paleocene and becoming extinct before the end of the Miocene (Miller 1947; Beu 1973; Chirat 2000; Nielsen et al. 2009; Goedert and Kiel 2016). In the Japanese Miocene deposits, four species of the genus *Aturia* have been recorded from ca. 30 localities (Tomida 1992), most of which are upper lower to lower middle Miocene in age (17-15 Ma). On the other hand, the occurrence of late Miocene *Aturia* is rare in Japan. This paper documents the occurrence of two *Aturia* specimens from an upper Miocene deposit at Utsunomiya, Tochigi Prefecture, central Japan, and briefly discusses its taphonomic and marine paleoclimatic implications. The specimens of *Aturia* are deposited at Tochigi Prefectural Museum, Utsunomiya, Japan (TPM).

Collecting locality, geologic age and paleoenvironment

Two *Aturia* specimens were confirmed from the Kinugawa section, an isolated outcrop of an unnamed Miocene deposit exposed along the Kinugawa River at Shimo-Okamoto, Utsunomiya City, Tochigi Prefecture, central Japan (Fig. 1A, B). The first specimen (TPM 8115) was collected by the author in 2003. During the preparation of this report, the second specimen (TPM 8116) was found as an unidentified specimen in the paleontological collection of the Tochigi Prefectural Museum. The Kinugawa section consists of ca. 10 m-thick, massive dark-grey siltstone that yields marine molluscs and calcareous microfossils (Hayashi et al. 2008). Cetacean skeleton fossils also have been excavated from the same section (Kashiwamura et al. 2013; Kimura et al. 2014). The stratigraphic horizon yielding molluscs and TPM 8115 are almost the same as loc. KN1n of Hayashi et al. (2008) (Fig. 1C). TPM 8116 was collected from the same section in 2001, but its occurrence horizon is unknown. Hayashi et al. (2008) analyzed the planktonic foraminiferal assemblages of the section and assigned them to the planktonic foraminiferal Zone N. 16 of Blow (1969), showing a lower upper Miocene (middle Tortonian) age. They also correlated the section with the upper Arakawa Group (stratigraphic interval between the upper part of the Ogane Formation and the Tanokura Formation), which is located ca. 15 km NE of the Kinugawa section.

Benthic molluscs including three bivalves and four gastropods were recognized from the same section: *Acharax* cf. *tokunagai* (Yokoyama), *Malletia inermis* (Yokoyama), *Lucinoma atutilineata* (Conrad), *Fissidentalium* sp., *Cryptonatica* sp., *Euspira* sp. and *Boreotrophon*? sp. They are partly in common with the molluscs from the upper Arakawa Group (e.g., Kurihara 2010; Matsui et al. 2011). All the specimens of *Acharax* and *Lucinoma* are conjoined, and a specimen of *Cryptonatica* bears its operculum within the aperture. This evidence suggests that these benthic molluscan species were autochthonous or para-autochthonous and inhabited an offshore (probably upper bathyal) muddy environment.

Description of *Aturia* specimens

The specimen TPM 8115 (Fig. 2A, B) is small (19 mm in maximum diameter), incomplete and depressed. No jaw apparatus was found together with it. The external surface of the shell is partly preserved, and the interior shell shows nacreous luster. There is no

Received: 18 February, 2019; Accepted: 22 May, 2019

*Department of Geology, Faculty of Education, Mie University, Tsu, Mie 514-8507, Japan
e-mail: ykurihara@edu.mie-u.ac.jp

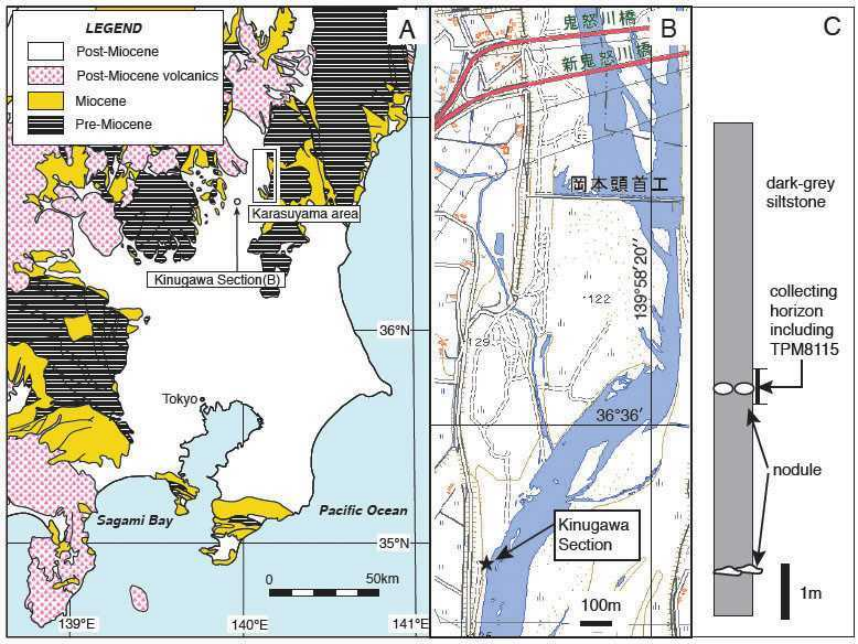
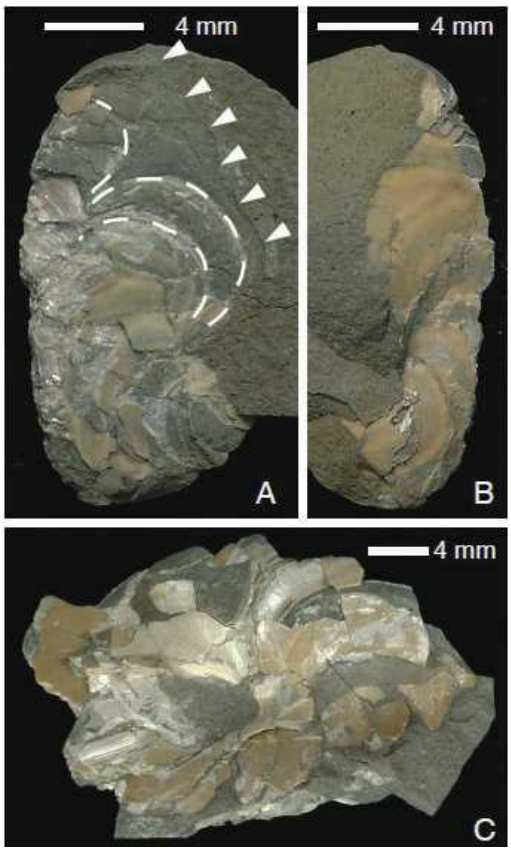


Fig. 1. A, Geologic sketch map of the northern Kanto region. B, Map showing the location of the Kinugawa Section. The topographic map is the "Houshakuji" sheet at 1:25,000 scale, published by the Geospatial Information Authority of Japan. C, Columnar section and fossil collecting horizon at the Kinugawa section (modified from Hayashi et al., 2008).



evidence of epibionts. Seven narrow and curved lateral saddles and a pointed lateral lobe are recognized, but ventral saddles are not preserved. In the left lateral view (Fig. 2A), the distance between the preserved outermost shell margin (white triangles) and the last septum (white arrows) is partly larger than that of the lateral saddles, suggesting that TPM 8115 is an incomplete phragmocone with its fragmental body chamber. The specimen TPM 8116 (Fig. 2C) is also a poorly preserved specimen with nacreous shell interior. It is larger (30 mm + in maximum diameter) than TPM 8115. The presence of a number of tiny shell fragments, it was partly damaged during the excavation. These characters indicate that these specimens are referable to the genus *Aturia*, but poor preservation prevents their specific identification.

Fig. 2. *Aturia* sp. A, B, Left and right lateral views, TPM 8115. White broken lines and triangles show the suture lines and fragmental shell margin, respectively. C, Right lateral view, TPM 8116. Both from the Kinugawa section (an unnamed lower upper Miocene bed) at Shimo-Okamoto, Utsunomiya City, Tochigi Prefecture, central Japan.

Shell preservation and taphonomy

Most Japanese Miocene *Aturia* specimens are incomplete phragmocones 50-100 mm in diameter (e.g., Tomida, 1992; Nakagawa 2018). The specimen TPM 8115 is also an incomplete phragmocone with its fragmental body chamber. The original shell diameter of TPM 8115 had to be less than 40 mm, because the body whorl occupies one third to half of the last whorl in the genus *Aturia* (e.g., Chirat 2000). This is one of the smallest specimens of Miocene *Aturia* ever recorded in Japan.

Postmortem shell dispersal over long distances has been emphasized in taphonomic studies of Miocene *Aturia* and other cephalopods (see Chirat 2000 and references therein), but this view conflicts with recent studies (e.g., Wani et al., 2005; Schlögl et al. 2011). Through field experiments with extant *Nautilus*, Wani et al. (2005) suggested that only large ammonoid shells (>ca. 200 mm in diameter) had the potential to drift postmortem over long distances and that most ammonoid shells (especially small ones) rapidly sank near their habitats, even if they once floated. Schlögl et al. (2011) reported the abundant occurrence of autochthonous small *Aturia* associated with jaw apparatuses from a lower Miocene bathyal deposit in Slovakia. Based on the oxygen isotopic results, they suggested that *Aturia* had a nektobenthic lifestyle at all stages of its development in bathyal depths. Taking these studies into consideration, the small shell size suggests that TPM 8115 sank rapidly near its habitat. This view, however, contradict the incomplete shell preservation and the lack of jaw apparatuses in TPM8115. Further research is needed to test this hypothesis with additional materials from the Kinugawa section.

Middle to Late Miocene *Aturia* after 15 Ma and marine paleoclimate

Miocene fossils of *Aturia* have been recorded from ca. 30 localities in Honshu, Japan, mostly from upper lower and lower middle Miocene strata with warm-water faunas (e.g., Tomida 1992; Noda et al. 1995; Ehiro et al. 2001; Tomida and Tanabe 2003). This time interval is almost equivalent to the Mid-Miocene Climatic Optimum (MMCO: 17-15 Ma), when the global climate became much warmer (Zachos et al. 2001). The most remarkable and exceptional *Aturia* locality of this time interval is Ogurui, Takahama Town, Fukui Prefecture, from where more than 1000 specimens of *A. cubaensis* have been found in the nearshore sandstone facies in association with tropical/subtropical molluscan assemblages (Kobayashi and Horikoshi 1958; Nakagawa 2009, 2018).

In contrast, the occurrences of middle to late Miocene *Aturia* after 15 Ma are rare in Japan (Table 1). This time interval is within a long-term cooling trend towards icehouse conditions. An exception is a warming event after 5.5 Ma (Holbourn et al. 2018), which may be related to the occurrence of *Aturia coxi* in the warm-water Zushi Fauna in central Japan (e.g., Ozawa and Tomida 1996). Records of early late Miocene *Aturia* specimens are known only from the offshore (probably upper bathyal) deposits in the Kinugawa section and the Haraichi Formation in Gunma Prefecture.

Planktonic foraminiferal assemblages from the Kinugawa section provide a clue for understating the marine paleoclimatic conditions inhabited by late Miocene *Aturia*. According to Hayashi et al. (2008), they are dominated by *Globigerina bulloides*, *Neogloboquadrina* spp. and *Globigerinita glutinata* with rare occurrences of the warm-water elements as *Globigerinoides* spp. and *Globoquadrina* spp. The species composition in the Kinugawa assemblages resembles those in the modern assemblages within a temperate mixed water region between the Kuroshio and Oyashio currents in the Pacific side of Honshu (i.e., off Boso Peninsula to off Onahama; see Oda and Takemoto 1992). Therefore, it is natural to infer that the specimen TPM 8115 inhabited temperate condition rather than tropical/subtropical conditions, because it is likely to have sunk rapidly near its habitat. As suggested by Nielsen et al. (2009) and Goedert and Kiel (2016), the tropical to subtropical nature of the genus *Aturia* might be expanded even to temperate conditions to some extent.

On the other hand, another explanation may account the occurrence of *Aturia* in the Kinugawa section. When Sakumoto et al. (1996) documented the occurrence of *Aturia* sp. in the upper part of the Fujina Formation in the Japan Sea side of southwest Japan, they considered the transportation of *Aturia* via warm-water current under the cool-temperate environment. A similar scenario can explain the occurrence of *Aturia* in the Kinugawa section. Further research is needed to test this scenario with additional materials from the Kinugawa section.

Acknowledgements

I thank S. Kawano (TPM) for inviting me to a

Table 1. Middle to Late Miocene occurrences of the genus *Aturia* in Japan after 15 Ma. Records from the Kokozura Formation that Tomida (1992) and Noda et al. (1995) considered to be upper middle to lower upper Miocene are excluded, because the age of the Kokozura Formation was revised to the lower middle Miocene by diatom biostratigraphy (Yanagisawa, 1996).

Species	Groups/Formations	Age of occurrence horizon	References
Aturia sp.	lower Tokigawa Gr.	"middle" middle Miocene	Hatai and Masuda (1962); Harada (2015)
Aturia cubaensis/ *A.* sp.	Fujina Fm.	"middle" middle Miocene	Tomida (1992); Sakumoto et al. (1996)
Aturia cubaensis/ *A.* sp.	lower Aoki Fm.	late middleMiocene	Tomida (1992); Koike and Narita (2008)
Aturia cubaensis	Amatsu Fm.	"late Miocene"	Tomida (1992)
Aturia cf. *cubaensis*	upper Haraichi Fm.	early late Miocene	Kurihara (unpublished)
Aturia sp.	unnamed	early late Miocene	This study
Aturia coxi	Senhata Fm.	latest Miocene	Tomida (1992)
Aturia coxi	Otsuki Fm.	latest Miocene	Ozawa and Tomida (1996)

symposium in 2018, organized by the Fossil Research Society of Japan and providing access to collection; H. Hayashi (Shimane Univ.) for sharing his knowledge of fossil and Recent planktonic foraminifers; A. G. Beu (GNS Science) and R. Wani (Yokoyama National Univ.) for their helpful comments on the early draft. H. Hayashi, Y. Horiuchi (Oita Himeshima Geopark Promotion Office) and K. Yajima (Kumagaya City) assisted with fieldwork in 2003. I appreciate G. Tanaka and an anonymous reviewer who made critical comments to improve this manuscript.

References

Beu AG (1973) Nautiloids of the genus *Aturia* from the uppermost Miocene of Australia and New Zealand. Sci. Rep. Tohoku Univ. 2nd Ser., Spec. Vol. 6 (Prof. Hatai Mem. Vol.), 297-308

Blow WH (1969) Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. In: Brönniman P, Renz HH (eds) Proceedings of the First International Conference on Planktonic Microfossils, Geneva, 1967, 1, E. J. Brill, Leiden, 199-422

Bronn HG (1838) Lethaea Geognostica oder Abbildungen und Beschreibungen der für die Gebirgs-Formationen bezeichnendsten Versteinerungen: Zweiter Band, das Kreide- und Molassen-Gebirge enthaltend. E. Schweitzerbart, Stuttgart

Chirat R (2000) The co-called 'cosmopolitan palaeobiogeographic distribution' of Tertiary Nautilida of the genus *Aturia* Bronn, 1838: the result of post-mortem transport by oceanic palaeo-currents. Palaeogeogr. Palaeoclimatol. Palaeoecol. 157, 59-77

Goedert JL, Kiel S (2016) A lower jaw of the nautiloid *Aturia angustata* (Conrad, 1849) from Oligocene cold seep limestone, Washington State, U.S.A. PaleoBios 33, 1-6

Ehiro M, Sato M, Takaizumi Y (2001) Occurrence of *Aturia* (Cephalopoda) from the Miocene Moniwa Formation of Sendai, Northeast Honshu, Japan and its paleoenvironmental significance. Earth Sci. (Chikyu Kagaku) 55, 183-186: in Japanese with English abstract

Harada Y (2015) Miocene invertebrate fossils from the Godo and Negishi Formations at Kuzubukuro, Higashimatsuyama City, Saitama, central Japan. 103-109, Reports on the Geology and Paleontology of the Kuzubukuro District, Higashimatsuyama City, Saitama Prefecture, Central Japan. Higashimatsuyama City Board of Education: in Japanese with English abstract

Hatai K, Masuda K (1962) Megafossils from near Higashi-Matsuyama City, Saitama Prefecture, Japan. Trans. Proc. Palaeontol. Soc. Japan N. S. 46, 254-262

Hayashi H, Tanaka Y, Watanabe M, Aoshima M (2008) Microfossil age of the Miocene sequence exposed along the Kinugawa River, Utsunomiya City, Tochigi Prefecture, central Honshu, Japan. Jour. Geol. Soc. Japan 114, 141-144: in Japanese with English abstract

Holbourn AE, Huhnt W, Clemens SC, Kochhann KGD, Jöhnck J, Lübbers J, Andersen N (2018) Late Miocene climate cooling and intensification of southeast Asian monsoon. Nature Comms. https://doi.org/10.1038/s41467-018-03950-1, 9(1), 1584

Kashiwamura Y, Kimura T, Aoshima M, Kogure K, Hasegawa Y (2013) Occurrence of cetacean fossils on the banks of the Kinugawa River in Shimo-Okamoto-cho, Utsunomiya City, Tochigi Prefecture, Japan. Bull. Tochigi Pref. Mus. 30, 9-16: in Japanese with English abstract

Kimura T, Hasegawa Y, Kashiwamura Y (2014) A fossil mysticete skeleton from the upper Miocene of

Tochigi Prefecture, Japan. Bull. Gunma Mus. Natu. Hist. 18, 87-100: in Japanese with English abstract

Kobayashi T, Horikoshi M (1958) Indigenous *Aturia* and some tropical gastropods from the Miocene of Wakasa in West Japan. Jap. Jour. Geol. Geogr. 29, 45-54

Koike H, Narita K (2008) Fossil Nautiloidae from the middle Miocene Aoki Formation in Azumino City, Nagano Prefecture, Japan. Res. Rep. Shinshushinmachi Fossil Mus. 11, 19-21: in Japanese with English abstract

Kurihara, Y (2010) Middle and late Miocene marine Bivalvia from the northern Kanto region, central Japan. Natl. Mus. Natr. Sci. Monogr. 41, 1-87

Matsui S, Yamamoto T, Kashiwamura Y, Nunokawa Y, Aoshima M (2011) The Neogene strata in Tochigi: stratigraphy and fossils of the middle part of the Arakawa Group and engineering geology of the Oya district. Jour. Geol. Soc. Japan 117 suppl., 89-102: in Japanese with English abstract

Miller AK (1947) Tertiary nautiloids of the Americas. Geol. Soc. Amer. Mem. 23, 1-234, pls. 1-100

Nakagawa T (2009) Miocene tropical sandy and rocky bottom molluscan assemblages of the Shimo Formation, Uchiura Group, Fukui Prefecture, central Japan. Bull. Mizunami Fossil Mus. 35, 127-151: in Japanese with English abstract

Nakagawa T (2018) Fossils of Ogurui, Takahama Town, Oi County, Fukui Prefecture. Fukui City Museum of Natural History, Fukui 78 p: in Japanese; title translated

Nielsen SN, Bandel K, Kröger B (2009) Palaeobiogeographical provenance, taphonomy, and mode of life of *Aturia cubaensis* (Cephalopoda, Nautiloidea) from Cainozoic deposits in Chile. Geobios 42, 73-88

Noda H, Kikuchi Y, Nikaido A (1995) Miocene *Aturia* (Cephalopoda, Mollusca) from Ibaraki, northern Kanto, Japan. Ann. Rep. Inst. Geosci. Univ. Tsukuba 21, 27-31

Oda M, Takemoto A (1992) Planktonic Foraminifera and paleoceanography in the domain of the Kuroshio current around Japan during the last 20,000 years. Quat. Res. 31, 341-357

Ozawa T, Tomida S (1996) Occurrence of *Aturia coxi* (Cephalopoda: Nautilida) from the uppermost Miocene of Japan and its implication for late Miocene marine climate in the northwestern Pacific. Jour. Paleont. 70, 795-798

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

Schlögl J, Chirat R, Balter V, Joachimski M, Hudáčková N, Quillévéré F (2011) *Aturia* from the Miocene Paratethys: an exceptional window on nautilid habitat and lifestyle. Palaeogeogr. Palaeoclimatol. Palaeoecol. 308, 330-338

Tomida S (1992) Taxonomic revision of Japanese Neogene *Aturia*. Bull. Mizunami Fossil Mus. 19, 223-245

Tomida S, Tanabe K (2003) A Nautilid cephalopod beak from the lower Miocene Ichishi Group, central Japan. Venus 62, 141-148

Wani R, Kase T, Shigeta Y, De Ocampo R (2005) New look at ammonoid taphonomy, based on field experiments with modern chambered nautilus. Geology 33, 849-852

Yanagisawa Y (1996) Diatom biostratigraphy of the Neogene Taga Group in Otsu District, Kitaibaraki City, Ibaraki Prefecture, Japan. Mem. Natn. Sci. Mus., Tokyo 29, 41-59: in Japanese with English abstract

Zachos JC, Pagani M, Sloan L, Thomas E, Billups K (2001) Trends, rhythms, and aberrations in global climate 65 Ma to present. Science 292, 686-693