Bulletin of the Mizunami Fossil Museum, no. 48, 119–126, 4 figs. ©2021, Mizunami Fossil Museum Manuscript accepted on December 14, 2021; online published on December 26, 2021 http://zoobank.org/urn:lsid:zoobank.org:pub:DFDC82A0-5BC4-40EE-98DA-41CFDD139686

Discovery of *Epistrenoceras* sp. (Ammonoidea) from the Middle Jurassic Series in Fukui Prefecture, Central Japan

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Abstract

Epistrenoceras sp. was newly found from the Lower Formation of the Kuzuryu Group, Fukui Prefecture in Central Japan. This genus occurs from the early Late Bathonian age in the Tethys Province and the southeastern Panthalassa. This is the first record of this genus in Japan. It indicates that the age of the Lower Formation of the Kuzuryu Group can be determined for the first time following the late Late Bathonian in age represented by *Pseudoneuqueniceras yokoyamai* from the Middle Formation of the Kuzuryu Group. The first occurrence in East Asia indicates that the habitat of this genus extended to western Panthalassa Ocean.

Key words: Epistrenoceras, early Late Bathonian, Kuzuryu Group, Fukui Prefecture, Central Japan

1. Introduction

The Middle Jurassic to Lower Cretaceous Tetori Group sensu lato as below is exposed mainly in Fukui, Ishikawa, Gifu and Toyama prefectures of northern Central Japan. Many ammonoids have been discovered from the upper reaches of the Kuzuryu River, Fukui Prefecture since the end of the 19th century (Yokoyama, 1904). By these ammonoids, biostratigraphic scheme of the Tetori Group (s.l.) has been built, e.g., the lowermost Pseudoneuqueniceras yokoyamai Assemblage Zone is correlated to the uppermost Bathonian (e.g., Sato and Westermann, 1991; Sato, 2008). Discovery of Epistrenoceras sp. could extend previous biostratigraphic correlation more lower. In this paper, systematic paleontology was made by M.G. and geologic outline was compiled by Y.S.

2. Geological setting

The Tetori Group (s.l.) in Fukui Prefecture was divided into the Kuzuryu, Itoshiro and Akaiwa subgroups, in ascending order (Maeda, 1961). In recent years, new stratigraphic schemes have been proposed based on the stratigraphic correlation with ammonoids, detrital zircon age and fission track dating (Sano et al., 2013; Sano, 2015; Yamada and Sano, 2018). According to Sano (2015), the Tetori Group (s.l.) is divided into the Kuzuryu and Tetori (s.s.) groups, in ascending order. This paper follows the stratigraphic division by Sano (2015). The Kuzuryu Group in the type locality: the Kuzuryu district is divided into the Lowest (Shimoyama Formation), Lower (Oidani and Tochimochiyama formations), Middle (Kaizara Formation) and Upper (Yambarazaka Formation) formations, in ascending order (Yamada et al., 1989; Sano, 2015) (Fig. 1). The Middle Formation is primarily composed of marine sediments containing abundant ammonoid (e.g., Sato, 1962) and belemnitid fossils (e.g., Maeda, 1961). The Kuzuryu Group is in fault contact with the Hida metamorphic rocks and is overlain unconformably by the Tetori Group (*s.s.*) (Sano, 2015; Sakai et al., 2020).

The Lowest Formation consists of predominant conglomerate with sandstone. The Lower Formation is exposed along the ridgeline route between Kaizara and Shimoyama (Fig. 2), consists of alternating beds of fine to coarse sandstone and thin mudstone. The sandstone of the alternating beds exhibits graded bedding or parallel laminations. Marine molluscs, such as ammonoid and belemnitid fossils have been recovered from this formation (Maeda, 1952; Sato et al., 1963; Goto and Handa, 2014). These fossils, however are not biostratigraphic index fossils. The Middle Formation is well-exposed along the Horadani Ravine at Kaizara, the Taniyamadani Ravine at Shimoyama, and the ridgeline route between Kaizara and Shimoyama (Fig. 2). This formation is composed of dark gray bedded or massive mudstone that infrequently includes calcareous nodules up to a few centimeters in diameter. Mottled trace fossils occur in the lower to middle parts of this formation. Ammonoid fossils are abundant in this formation (e.g., Sato, 1962, 2008). A belemnitid fossil (Sano et al., 2010), a fish scale (Yasuno, 1995), plant fossils (Yamada and Uemura, 2008), and microfossils including radiolarians, benthic foraminifera, prodissoconchs of juvenile bivalves (Kashiwagi and Hirasawa, 2015) have also been discovered. The depositional environment of the Middle Formation is interpreted to be a bay or inner bay (Yamada et al., 1989). The Upper Formation is distributed on the northeast side of the Middle Formation (Fig. 2). This formation consists of alternating beds of medium to coarse sandstone and mudstone.

The present ammonite specimen (OMFJ-437) was recovered from a cliff along a ridgeline of Mt.

Tochimochiyama (Loc. 1 in Fig. 2), where the strata of the Kuzuryu Group typically strike NW-SE and dip 60–90°N, except some overturned strata. The Kuzuryu Group around Mt. Tochimochiyama consists of 1) the lower part of the Lower Formation composed of alternating bed of sandstone and mudstone, 2) the upper part of the Lower Formation composed mainly of medium to coarse sandstone, 3) the uppermost part of the Lower Formation composed of conglomerate, and 4) the Middle Formation composed of mudstone, in ascending order (Fig. 3). The stratigraphic level of OMFJ-437-bearing bed is within the lower part of the Lower Formation.

3. Systematic description

Specimen described here is deposited in the Izumi Local History Museum, Ono City, Fukui Prefecture, Central Japan (Registration code-OMFJ). Morphological terminology and systematic classification basically followed Arkell et al. (1957). The following abbreviations were used in the descriptions: D for shell diameter, U for umbilical diameter, U/D for ratio of umbilical diameter to shell diameter, H for whorl height.

Superfamily Perisphinctoidea Steinmann, 1890 Family Parkinsoniidae Buckman, 1920 Genus *Epistrenoceras* Bentz, 1928

Epistrenoceras sp.

(Fig. 4)

Type specimens: d'Orbigny (1846) does not specify holotype. Lost syntypes are two specimens designated by d'Orbigny (1846, pl. 145, figs. 1–5); Existing syntypes, MNHN A27499 collected by d'Orbigny, from Niort (46° 19' 48" N; 0° 27' 36" E), Deux-Sèvres, Poitou-Charentes, France. MNHN A27499 is deposited in National French Museum of Natural History (du Muséum national d'Histoire naturelle).

Material: Single specimen, OMFJ-437, from Loc.1 in Figs. 2, 3.

Measurement: D = 26.0 mm, U = 9.4 mm, H = 10.0 mm, U/D = 0.36.



Fig. 1. Stratigraphic correlation table of the Kuzuryu Group. Biostratigraphy is adopted from Sato and Westermann (1991).

Description: Right side of an immature shell is available for study. This specimen is partially deformed and broken, but it has very characteristic ribs. Whorl is evolute with flat to slightly rounded flank, subrounded ventral shoulder (Fig. 4a). Sharp prorsiradiate primary ribs rising from near the umbilical margin and showing bladelike elevation on the inner flank, then suddenly bend backward forming chevron at ventrolateral shoulder, and become strongly rursiradiate and bipartite at ventral periphery. Sharp tubercles appear on the ribs at ventrolateral shoulder (Fig. 4b, c). There is an insert single rib near the aperture. The number of primary ribs is 13 in half of the outermost whorl. Even with consideration of shell deformation, the interval between the ribs is irregular. It is difficult to observe the venter and the inner whorl ornamentation due to remarkable deformation and damage. Umbilical wall is rounded. Suture line is unknown.

Comparison and affinity: Since this specimen is a juvenile as a growth stage, it was judged difficult



Fig. 2. Geological map around Mt. Tochimochiyama in the Kuzuryu district, Fukui Prefecture, Central Japan (modified from Sakai et al., 2020).

to determine the species, but compared with the following species. This specimen resembles to *Epistrenoceras contrarium* (d'Orbigny) (1846, p. 418, pl. 145, figs. 3–4), from Niort of Deux-Sèvres, western France, by evolute shell, suddenly bending ribs, dense ribbing and sharp chevron-type ribbing, but the former is three-fifths the size of the latter. The former has biplicate secondary ribs, whereas the latter has rarely them. In the U/D value, the former is 0.36 and the latter is 0.38. Another specimen of *E. contrarium* (d'Orbigny, 1846, p. 418, pl. 145, figs. 1–2) has a U/D value of 0.51.

E. contrarium (d' Orbigny, 1846, p. 418, pl. 145, figs. 3–4) was given a new species *E. histricoides* by Rollier (1911), due to its smaller size and more vigorous and less dense ribbing than that of other specimens of *E. contrarium* (d'Orbigny, 1846, p. 418, pl. 145, figs. 1–2). However, Dietl (1978) regarded *E. histricoides* as the microconch of *E. contrarium* because of the considerable variation in the rib density of *E. contrarium*. Further, the U/D values of both are very different depending on the expansion rate of the whorls, however both are classified as the same species due to their evolute

shells, hexagonal whorl sections, and characteristic chevron-type ribbing (Howarth, 2017). This specimen is similar to *E. histricoides* (Sandval et al., 1990, pl. 9, fig. 7) in having almost the same U/D value. But the latter is different from the former by constrictions and more number of wider blunt primary ribs (16 in half of the outermost whorl).

This specimen is similar to *E*. aff. *histricoides* (Westermann et al., 1984, pl. 2, figs. 3–7) from the late Bathonian sequence of Cualac, Mexico, in having bifurcated sharp primary ribs at the ventral shoulder. But the latter is different from the former by more dense ribs and shallower umbilicus. The number of primary ribs of the latter is 14 to 17 in half of the outermost whorl, and U/D values are 0.31 to 0.34.

This specimen is also similar to *E. subcontrarium* (Behrendsen, 1886, p. 23, pl. 2, figs. 1a–d), from the collection of the Lord Governor Mr. Hoyer in Hanover, in having sharp ribs arising from dorsal area, bending ribs behind and biplicate secondary ribs, but it is clearly different from the latter by bending point of the ribs on the flank, the number of main ribs. The bending point of the rib is that the former seems to be on the ventral shoulder, whereas the latter is in the center of the flank. The latter is about 11 for the number of ribs in the half whorl.



Fig. 3. Stratigraphic section of the Kuzuryu Group around Mt. Tochimochiyama.

Occurrence: Epistrenoceras is known occurrence, Europe (e.g., d'Orbigny, 1846, pl. 145, 1–2; Douvillé, 1915, pl. 7, fig. 1; Sturani, 1966, pl. 21, figs. 4–6), India (Kayal and Bardham, 1998, pl. 1), Madagascar (Collignon, 1958, pl. 8, figs. 42–44), Mexico (e.g., Burckhardt, 1927, p. 90, pl. 16, figs. 10–16, Westermann et al., 1984, pl. 2, figs. 3–7, Sandval et al., 1990, p. 121–122, pl. 9, figs. 6–8), Peru (e.g., Westermann et al., 1980, p. 31, 37) and Chile (e.g., Fernandez-Lopez et al., 1994, pl. 1, fig. 2). The described specimen originated from the Lower Formation of the Kuzuryu Group, Fukui Prefecture, Central Japan. The first occurrence in East Asia indicates that the habitat of this genus extended to western Panthalassa Ocean.

4. Implications on biostratigraphy of the Kuzuryu Group

Epistrenoceras occurs from the Retrocostatum Ammonite Standard Zone indicating the lower Upper Bathonian of the Sub-Mediterranean region (e.g., Page et al., 2004; Branger, 2009; Mönnig and Dietl, 2017). Because the Pseudoneuqueniceras yokoyamai Assemblage Zone of the lowest zone in the Middle Formation of the Kuzuryu Group is correlated to the Discus Ammonite Standard Zone of the uppermost Bathonian (Sato and Westermann, 1991), stratigraphic level of *Epistrenoceras* is obviously below the Pseudoneuqueniceras yokoyamai Assemblage Zone (Fig. 1), and in present knowledge, it represents the lowest biostratigraphic datum of ammonites in the Kuzuryu Group.

5. Conclusion

The present specimen is first discovered in Japan. The habitat of *Epistrenoceras* is known not only from the Tethys Ocean and the Southeast Panthalassa Ocean, but also from the Western Panthalassa Ocean. *Epistrenoceras* clearly indicates a genus taking in the Retrocostatum Ammonite Standard Zone of Sub-Mediterranean region. The geological age of this specimen from the Lower Formation of the Kuzuryu Group is judged to be early Late Bathonian.



Fig. 4. *Epistrenoceras* **sp.** from the Lower Formation of the Kuzuryu Group around Mt. Tochimochiyama, OMFJ-437. *a*, Lateral view; *b*, Ventral view showing sharp primary ribs like blades; *c*, Oblique view showing sudden weakness of sharp primary ribs and biplicate sharp secondary ribs at the ventral shoulder. Scale bars = 5 mm.

6. Acknowledgements

The authors would like to express our appreciation to Professor Emeritus Tadashi Sato (University of Tsukuba, Japan) for their useful opinions in identifying the specimen. The authors thank Dr. Kentaro Nakada (Fukui Prefectural Dinosaur Museum, Japan) for his constructive comments on the manuscripts. The authors would like to thank Enago (www.enago.jp) for the English language review.

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