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A gigantic ammonite from the Upper Jurassic Arimine Formation of the Tetori Group, Japan

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Abstract

A gigantic ammonite specimen discovered from the Arimine Formation of the Tetori Group in the eastern part of the Jinzu section is described as *Perisphinctes* (*Kranaosphinctes*) *matsushimai* Yokoyama. The specimen, measuring over 25 cm in diameter, is one of biggest specimens reported from the Tetori Group. The occurrence of the species suggests that the Arimine Formation can be assigned to the *Perisphinctes matsushimai* Assemblage Zone of Middle Oxfordian, Late Jurassic. The Kiritani Formation, distributed in the western part of the Jinzu section, also contains fossils assigned to the *Perisphinctes matsushimai* Assemblage Zone and is thus correlative with the Kiritani Formation. Both formations were deposited during the first transgressive phase in the Tetori area.

Key words: gigantic ammonite, Arimine Formation, *Perisphinctes* (*Kranaosphinctes*) *matsushimai*, Middle Oxfordian

Introduction

As late Mesozoic terrestrial deposits are widely distributed on the Asian continent and include various kinds of zoo- and phyto-assemblages, they are suitable for understanding the changes of terrestrial environments and their accompanying terrestrial and fresh-water biotas. To help understand this significance, a suitable chronological scale for these deposits is required.

There are marine intercalations within the upper Mesozoic nonmarine successions of the eastern part of the Asian continent, including the eastern part of the Heilongjian Province, China and the Tetori area, Japan. It is, therefore, possible to assign the marine stage nomenclature for these nonmarine deposits. We can, then, discuss the changes of terrestrial environments and their accompanying terrestrial and fresh-water biota.

The Tetori Group is represented by different outcrops in the Mt. Hakusan and Jinzu sections. Recently, two stratigraphic sequences of the group in the Mt. Hakusa area were redefined as lithostratigraphic units of the group and the unified definitions and nomenclature for these strata were given (Matsukawa et al., 2006, 2007). Then, based on occurrence of ammonites, the Tetori Group is correlated with Callovian to Oxfordian, Tithonian to Berriasian and Hauterivian to Barremian (Sato, 1962; Sato and Westermann, 1991; Sato et al., 2003,2008; Matsukawa et al., 2007).

The Tetori Group in the Jinzu section reflects the eastern distribution of the group and consists small, localized

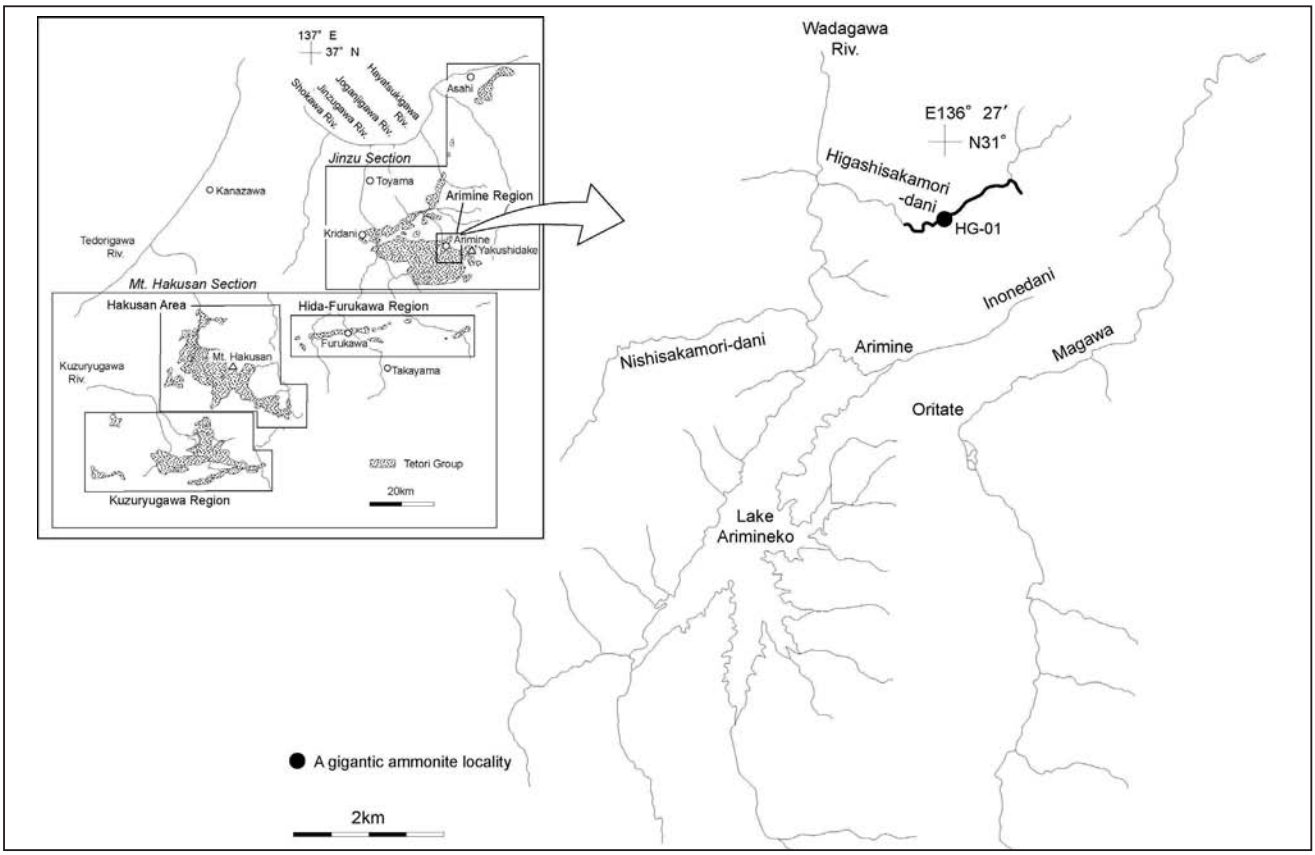

Fig. 1. Map showing ammonite locality in the Arimine region. Thick line represents the route along which columnar section of the Arimine Formation (Fig. 2) was measured along Higashisakamori-dani Creek. Index map shows distribution of the Tetori Group in two sections.

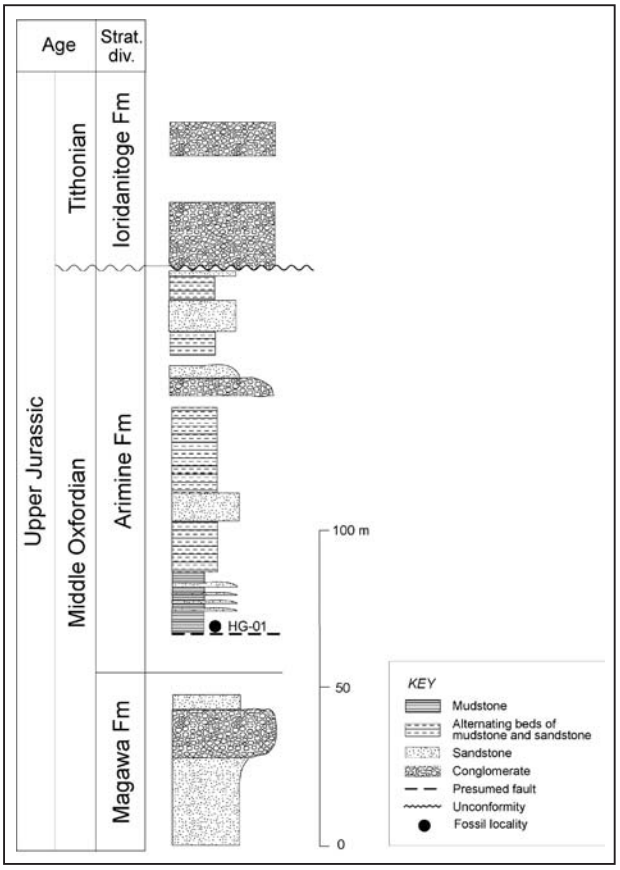

Fig. 2. Columnar section of the Tetori Group along the Higashisakamori-dani Creek, Toyama Prefecture, Japan.

marine deposits in its lower part and widespread terrestrial deposits in its upper part. Although there are diverse opinions about the stratigraphy of the upper part of the Tetori Group in the Jinzu section (Maeda and Takenami, 1957; Kawai and Nozawa, 1958; Takenami and Maeda, 1950), there is an accordance of opinion concerning its lower marine deposits. These marine deposits are assigned to two formation, the lower, Magawa and upper, Arimine formations (Figs. 1, 2). To date, an occurrence of the Jurassic ammonite *Kranaosphinctes* sp. in the Arimine Formation was listed by Maeda and Takenami (1957), who showed the formation can be correlated with the Oxfordian stage. Subsequently, *Kranaosphinctes* sp. from the Arimine Formation has been used as an age constraint for the Oxfordian in a number of geological studies, including these of Kawai and Nozawa (1958), Takenami and Maeda (1959), Maeda (1961), Toyama Prefecture (1992), and Toyama Board of Education (2002). However, paleontological descriptions and illustrations of ammonite specimens from the Arimine Formation have not yet been presented.

We collected a gigantic ammonite specimen identified as *Perisphinctes* (*Kranaosphinctes*) *matsushimai* Yokoyama from Higashisakamori-dani creek in Arimine area, Toyama Prefecture, Japan. The specimen measures over 25 cm in diameter and preserves the original shape and surface ornamentation. This species was named as *Perisphinctes* (*Procerites*) *matsushimai* by Yokoyama (1904) based on specimens from the Jurassic shale in Echizen province (present Fukui Prefecture). Sato and Westermann (1991), then, used *Perisphinctes* (*Kranaosphinctes*) *matsushimai* as an assemblage zone species of the *Perisphinctes* (*Kranaosphinctes*) *matsushimai* Assemblage Zone, assigning the zone to the Middle Oxfordian, with the Yambarazaka Formation in Kuzuryu area in Fukui Prefecture as type locality.

In this paper, we present a paleontological description of the specimen from the Arimine area and discuss the age of the Arimine Formation.

Geological setting

The Tetori Group is one of the principal late Mesozoic, dominantly terrestrial deposits of East Asia, with commonly found taxa in the area. The Tetori Group is distributed in two separate locations, the Mt. Hakusan and Jinzu sections. The Mt. Hakusan section contains the main "type" stratigraphic sections of the group and bears rich zoo- and phyto-fossils. There are three stratigraphic sequences of the group in the Mt. Hakusan section: the Kuzuryugawa sequence, the Hakusan sequence and the Hida-Furukawa sequence (Matsukawa et al., 2006, 2007) (Fig. 3). In the Kuzuryugawa region, the group can be divided into eight formations: the Shimoyama, Tochimochiyama, Kaizara, Yambarazaka, Yambara, Ashidani, Izuki and Nochino formations in ascending order. In the Hakusan area, the group can be divided into nine units: the Ushimaru Formation, Mitarai Formation,

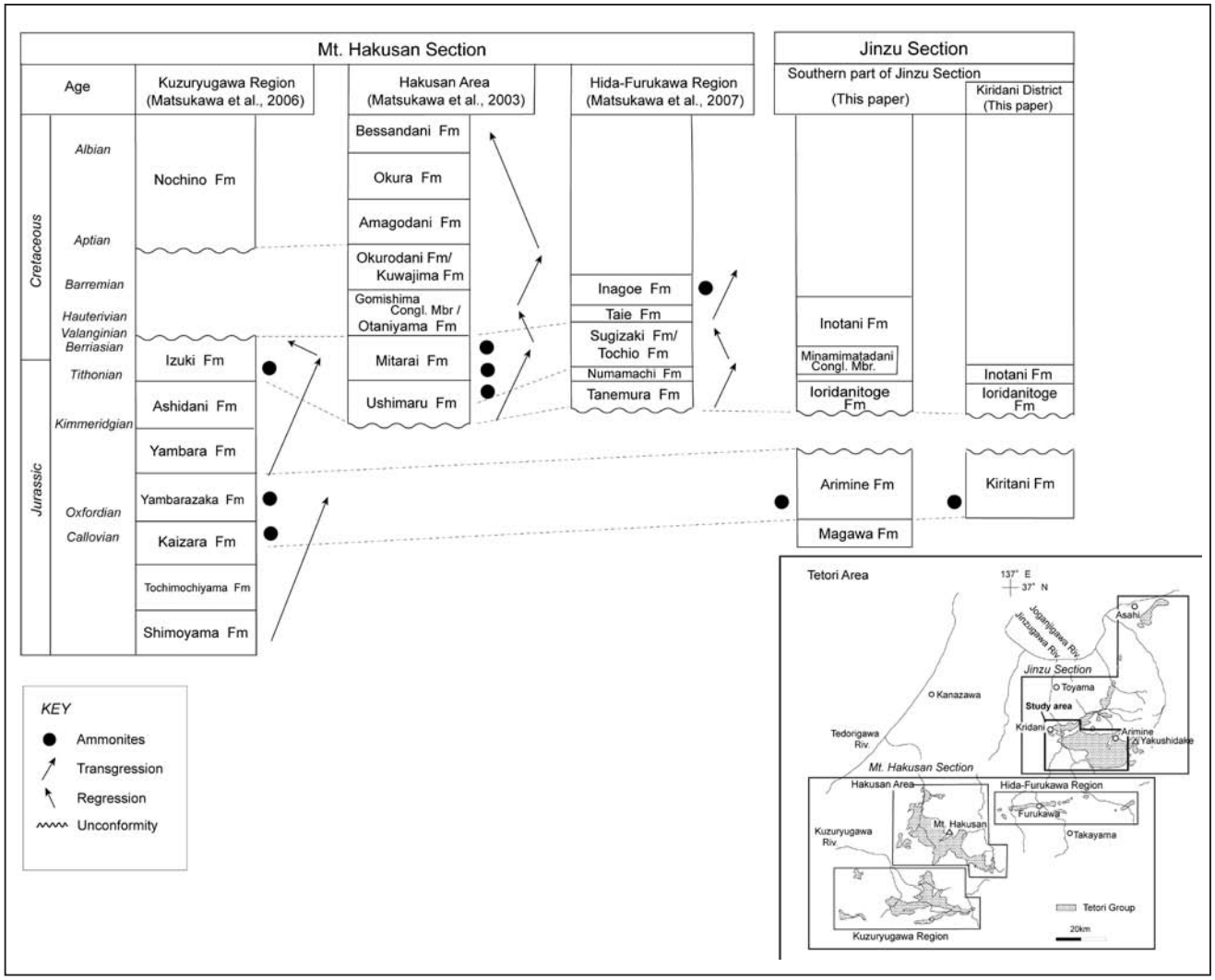

Fig. 3. Geological correlation of the Tetori Group between Hakusan and Jinzu sections based on ammonite indices and marine trangressive phases.

Otamiyama Formation /Gomishima Conglomerate Member, Okurodani Formation /Kuwajima Formation, Amagodani Formation, Okura Formation and Bessandani Formation in ascending order. Then, in the Hida-Furukawa region, the group can be divided into six formations: the Tanemura, Numamachi, Sugizaki/Tochio, Taie and Inagoe formations, in ascending order.

Ammonites are found in the Kaizara and Yambarazaka formations in the Kuzuryugawa region, in the Ushimaru and Mitarai formations in the Hakusan area, and in the Inagoe Formation in the Hida-Furukawa region. Ammonite indices suggesting Callovian and Oxfordian ages occur in the Kaizara and Yambarazaka formations, suggesting that Tithonian to Berriasian exists in the Ushimaru and Mitarai formations and suggesting that the Hauterivian to Barremian are present in the Inagoe Formation. Consequently, three sequential marine transgressions can be recognized in the Tetori area: Middle to Late Jurassic Callovian to Oxfordian, Jurassic – Cretaceous transition from Tithonian to Berriasian, and Early Cretaceous Hautervian to Barremian.

In the Jinzu section, the Tetori Group can be divided into five formations and one member in ascending order: the Magawa, Arimine/Kiritani, Ioridanitoge, and Inotani formations, and the Minamimatadani Conglomerate Member. Five units, the Magawa and Arimine formations of the lower part of the group, and the Ioridanitoge and Inotani formations and the Minamimatadani Conglomerate Member, in the upper part, can be recognized in the Tetori Group. Based on lithologic characteristics and fossil evidence, the lower unit consisting of the Magawa and Arimine formations suggests shallow marine environments, while the unconformably overlying upper unit, consisting of the Ioridanitoge and Inotani formations and the Minamimatadani Conglomerate Member, suggest allvial fan and meandering river environments.

A gigantic ammonite has been collected from black shale of the lower part of the Arimine Formation along Higashisakamori-dani creek in the Arimine region.

Systematic description

Repository. The specimen illustrated is deposited in the Department of Environmental Sciences, Tokyo Gakugei University, Koganei. Tokyo (TGUSE).

Terminology. In general, morphological terminology follows Arkell et al. (1957), and adjectives used in descriptions are in accordance with the definition of Matsumoto (1988).

Abbreviation. D: diameter; U: umbilicus (expressed as a percentage of diameter); H: whorl height; W: whorl width; W/H: width/height ratio.

Class: Cephalopoda von Zittel, 1884

Order: Ammonoidea von Zittel, 1884

Suborder Ammonitina Hyatt, 1889

Superfamily Perisphinctaceae Steinmann, 1890

Family Perisphinctidae Steinmann, 1890

Subfamily Perisphictinae Steinmann, 1890

Genus *Perisphinctes* Waagen, 1869

Subgenus *Kranaosphinctes* Buckman, 1921

Perisphinctes (*Kranaosphinctes*) *matsushimai* Yokoyama, 1904

1904 *Perisphinctes* (*Procerites*) *matsushimai*; Yokoyama, p. 3-4; pl. 1, fig. 1.

1962 *Kranaosphinctes matsushimai*; Sato, p.86-88; pl. 2, figs. 4a, 8; pl. 7, figs. 1, 2, 3, 4, 5; pl. 9, fig. 7.

1972 *Kranaosphinctes matsushimai*; Suzuki and Sato, p.214-215, fig. 2.

1990 *Kranaosphinctes matsushimai*; Shimonoya and Takahashi, pl. 25, fig. 4.

2002 *Kranaosphinctes matsushimai*; Fukada, pl. 2, fig. 2.

Material. A single specimen, TGUSE-MM 5220 (K. Koarai and Y. Ogawa Coll.), from the lowermost black mudstone unit of the Arimine Formation (Higashisakamori-dani Creek).

Measurements (in mm).

Specimen	D	U	H	W/2	(W/2)/H
TGUSE-MM 5220	278(1)	ca130(0.47)			
Half-whorl earlier, costa			68.8		
Half-whorl width, costal				27.6	0.80

Description. The specimen is very large, ca. 280 mm in diameter, with moderately involute whorl with a fairly wide umbilicus, <50 % of diameter in later growth-stage, being moderate in early growth-stage. Whorl is polygyral

Fig.4. ***Perisphinctes*** **(*Kranaosphinctes*)** ***matsushimai*** **Yokoyama, 1904 from the Arimine Formation in Higashisakamoridani-Creek, Toyama. Scale shows 5 cm.**

and shows subtrapezoidal cross-section with somewhat convex flanks, and much compressed, with W/H about 0.40 in later growth-stage.

Surface is ornamented by primary, secondary, and intercalated ribs. Primary ribs are narrow and sharp, forming subtriangle sections and arising at the umbilical margin. They branch into four or five secondary ribs at one-fourth of the distance along the flank from the ventral margin. Intercalated ribs present are between secondary ribs. Deep and wide constrictions, appear periodically, crossing both secondary and iniercalated ribs.

Remarks. Specimen is similar to the illustrated specimen of *Kranaosphinctes matsushimai* from the probable Yambarazaka Formation, Tetori Group, at Nagano, Fukui Prefecture (Shimonoya and Takahashi, 1990, pl. 25, fig. 3), in having four secondary ribs branched from primaries. Variable ribbing patterns can be recognized on specimens identified as *Kranaosphinctes matsushimai* from the Tetori Group in Japan (Fig. 5). For example, the holotype of *Perisphinctes* (*Procerites*) *matsushimai*,

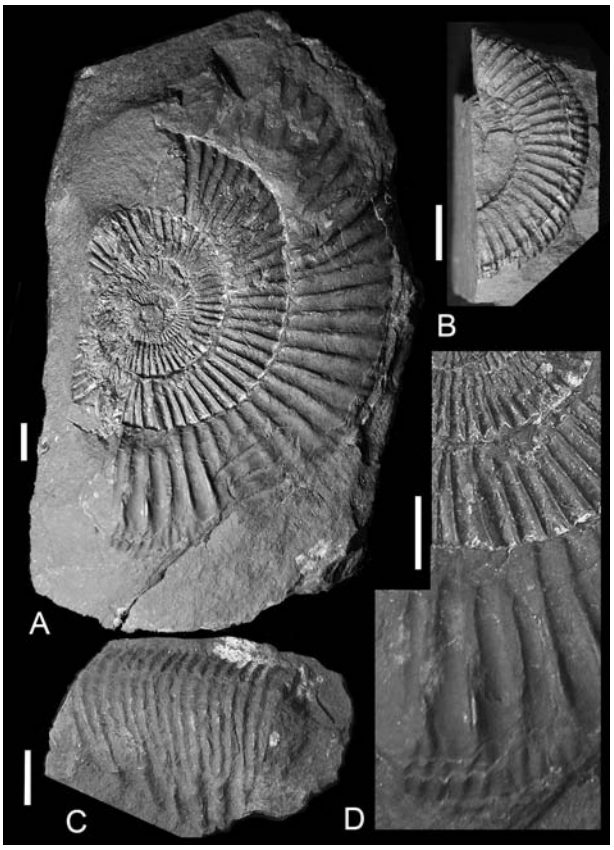

Fig. 5. Comparison of secondary ribbing of specimens identified as *Perisphinctes* (*Kranaosphinctes*) *matsushimai* Yokoyama. A and D are the holotype, UMUT MM7054; D shows enlarged part of later stage of shell. B is UMUT 3789. C is UMUT 3785. Scale bars show 1cm.

(UMUT MM7054, University Museum of the University of Tokyo), from the Yambarazaka Formation, Tetori Group, at Nagano, Fukui Prefecture (Yokoyama, 1904, pl. 1, fig. 1), has three secondary ribs at early growth-stage, and two secondary and intercalated ribs at its continuously later growth-stage. As well, the specimen of *Kranaosphinctes matsushimai* from the Yambarazaka Formation, Tetori Group, at Nakajima, Fukui Prefecture (UMUT MM3789)(Sato, 1962, pl. 2 fig. 6) has single primary ribs at early growth-stage, and two secondary ribs, intercalated ribs and sometimes a single primary rib at its continuously later stage. The specimen of *Kranaosphinctes matsushimai* from the Yambarazaka Formation, Tetori Group, at Nagano, Fukui Prefecture (UMUT MM3785) (Sato, 1962, pl. 2, fig. 5, pl. 7, fig. 1) displays two secondary ribs. The sparse primary ribbing of the present specimen is similar to that seen on the illustrated specimen of Kranaosphinctes matsushimai (Fukada, 2002, pl. 2, fig. 2), held at the Omori Inn at Oginohama, Miyagi Prefecture; this specimen is now housed at the Fukada Geological Institute, Tokyo. Kranaosphinctes matsushimai (Suzuki and Sato, 1972, p. 214-215, fig. 2), probably from the Torinoko Formation at Ohira, Mashiko, Tochigi Prefecture, also shows similar sparse ribbing, but this specimen, typically, has triplicate secondary ribs, while our specimen has four or five secondary ribs. The illustrated specimen (IGPS 7178, University Museum of the Tohoku University) of Kranaosphinctes cf. matsushimai from the Oginohama Formation at Aritahama, south of Oginohama, Ishinomaki city, Miyagi Prefecture, northeast Japan (Takahashi, 1969, pl. 14, fig. 5), is also different from the present specimen in having dense primary ribs.

Although Glowniak (2002) defined the subgenus *Kranaosphinctes* as having bifurcate secondary ribs and intercalatory ribs between the secondaries, variable ribbing patterns can be recognized in Japanese specimens assigned to the subgenus. Almost all Japanese specimens possess constrictions and can thus be identified as the subgenus *Kranaosphinctes* based on the criteria of Arkell et al. (1957).

Occurrence. Middle Oxfordian (Arimine Formation) of Higashisakamori-dani creek, Toyama Prefecture, Japan.

Geological age of the Arimine Formation of the Tetori Group

Sato and Westermann (1991) showed the Jurassic regional ammonite zones of East Asia and Southeast Asia, including Japan, the Philippines, Thailand and Indochina, Indonesia, and N.W. Papua-New Gunea. Regarding Japan, thirteen regional zones, consisting of three Lower Jurassic zones, seven Middle Jurassic zones, including the *Hosoureites ikianus* Assemblage Zone which ranges down into the Upper Toarcian, and three Upper Jurassic zones were distinguished. Four of these Middle and Upper Jurassic zones were recognized within the Tetori Group in Mt. Hakusan section; the *Pseudoneuqueniceras yokoyamai* Assemblage Zone is defined in the lower part of the Kaizara Formation of the Tetori Group as type zone,;the *Kepplerites japonicus* Assemblage Zone, indicating earliest Callovian, is defined in the middle part of the Kaizara Formation as type zone; the *Oxycerites* Assemblage Zone, indicating Early Callovian, is defined in the upper Kaizara Formation as type zone; and the *Perisphinctes matsushimai* Assemblage Zone, indicating Middle Oxfordian, is defined in the Yambarazaka Formation of the Tetori Group as type zone.

As a gigantic ammonite specimen from the Arimine Formation is identified as *Perisphinctes* (*Kranaosphinctes*) *matsushimai* Yokoyama, the Arimine Formation can be correlated with the Yambarazaka Formation of the Tetori Group of the Mt. Hakusan Section, and can be assigned to the Middle Oxfordian. Previousely, Maeda and Takenami (1957) suggested the Arimine Formation can be correlated with the Oxfordian based on *Perisphinctes* sp. Our study supports this previous study.

Geological correlation and environments

There are two isolated distributions of marine rocks within the dominantly nonmarine Tetori Group in the Jinzu section. In the eastern exposures of the Jinzu section, the marine formation is named as the Kiritani Formation, and in the western section, the marine sequence is subdivided into the Magawa and Arimine formations, in ascending order. These marine formations are all unconformably overlain by the Ioridanitoge Formation, consisting of alluvial fan deposits.

The Kiritani Formation consists mainly of coarse sandstone and bears abundant specimens of the genus *Nipponitrigonia*. *Perisphinctes* (*Dichotomosphinctes*) *kiritaniensis* Sato is also noted in the formation (Sato, 1962). Based on Sato and Westermann (1991), the Kiritani Formation is defined of the *Perisphinctes matsushimai* Assemblage Zone, indicating Middle Oxfordian. This suggests that the Kiritani Formation can be correlated with the Arimine Formation. Based on lithologic characteristics of their molluscan fossil-bearing units, the Kiritani Formation is characterized by coarse sandstone and conglomerates while the Arimine Formation is characterized by black shale and muddy sandstone. The common molluscan species are rare in both formations; the Kiritani Formation bears common specimens of the genus *Nipponitrigonia* while the Arimine Formation bears abundant specimens of the genus *Myophollera* but no record of the genus *Nipponitrigonia*. The different molluscan assemblages suggest that both formations reflect different depositional environments. Tashiro and Matsuda (1988) interpreted that the genus *Nipponitrigonia* inhabited shallow-marine beach environments. The genus *Myophollera* ornamented with many nodes on its shell surfaces, can be interpreted to inhabit mud bottoms in the deep sea, as Stanley (1970) shows relation between these shell characteristics and such environments. Based on environmental differences of trigonians, the Kiritani Formation in the west seems to be shallower than the Arimine Formation in the east. This concurs with the hypothesis that western hinterland to the Tetori Group depositional basin existed during the Late Jurassic (Matsukawa et al., 1997).

Matsukawa et al. (2007) showed three sequentional marine transgressions can be recognized in the Tetori area, during Callovian to Oxfordian, Tithonian to Berriasian, and Hauterivian to Barremian, while two marine transgressions, late Oxfordian to Volgian (approximately equivalent Tithonian to early Berriasian) and Barremian to Aptian, can be recognized in the Heilongjiang area of

China. Consequently, two regional marine transgressive events, Oxfordian to Berriasian and Barremian to Aptian, are recognizable along the east margin of the Asian continent during Late Jurassic to Early Cretaceous time. Discrepancies in the timing of marine transgressions between the Tetori and Heilongjiang are considered to be caused by differences in regional diastrophism and the distances of the basins from the ocean. Therefore, the Arimime and Kiritani formations appear to have been deposited during the first marine trangression in the Tetori area.

Conclusions

1. A gigantic ammonite has been found in the Arimine Formation of the Tetori Group. This specimen is identified as *Perisphinctes* (*Kranaosphinctes*) *matsushimai* Yokoyama, over 25 cm in diameter and is one of the biggest ammonite specimens reported from the Tetroi Group.
2. From the occurrence of *Perisphinctes* (*Kranaosphinctes*) *matsushimai* Yokoyama, the Arimine Formation can be assigned to the *Perisphinctes matsushimai* Assemblage Zone of Middle Oxfordian, Late Jurassic.
3. The Arimine Formation is developed in the eastern part of the Tetori Group basin and is correlated with the Kiritani Formation which is found in the western part of the basin. Rare molluscan species common to the two formations show that the two formations represent different depositional environments. Based on environmental differences of trigonians, the western Kiritani Formation appears to be shallower than the eastern Arimine Formation. This concurs with the hypothesis of western hinterland to the depositional basin of the Tetori Group in the Late Jurassic.
4. The Arimine and Kiritani formations were deposited during the first marine trangressive event in the Tetori area.

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【要　旨】

上部ジュラ系有峰層（手取層群）から産出した巨大なアンモナイト

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富山県東部の手取層群の有峰層から産出した巨大なアンモナイトは，*Perisphinctes (Kranaosphinctes) matsushimai* Yokoyamaに分類・同定され，本論文で古生物学的に記載される．記載する標本は，直径25cmを越え，これまで手取層群から報告されたアンモナイトの中で最も大きいものの１つである．このアンモナイト種は日本ではジュラ紀後期のオックスフォーディアン期中期を指示するPerisphinctes matsushimai帯の示帯種なので，この種の産出により有峰層はその時代を示す．従って，有峰層は富山県下に分布する桐谷層に対比され，両層は手取地域における最初の海進期に堆積したものであると解釈できる．