The Occurrence of the Large Gastropod "*Pleurotomaria*" *Yokoyamai* Hayasaka from the Capitanian (Permian) Iwaizaki Limestone in Northeast Japan

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The occurrence of the large gastropod "*Pleurotomaria*" *yokoyamai* Hayasaka from the Capitanian (Permian) Iwaizaki Limestone in Northeast Japan

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Abstract. The Permian large gastropod *"Pleurotomaria" yokoyamai* Hayasaka was found for the first time from the Capitanian (upper Guadalupian) Iwaizaki Limestone in the South Kitakami Belt, Northeast Japan. A smaller planispiral gastropod *Porcellia* sp. was found in association with it. These taxa have been scarcely reported, except from the coeval Permian limestones at Akasaka in Southwest Japan and in the Balya Maden area, western Turkey. The Akasaka Limestone was deposited as a low-latitude atoll on a mid-Panthalassan seamount, whereas the Iwaizaki Limestone was laid down as a patch reef within a terrigenous clastics-dominated facies on a shallow marine continental shelf. The occurrence of this unique assemblage suggests that the Iwaizaki Limestone originated also in a Permian low-latitude domain, and that the South Kitakami Belt likely formed a part of the continental margin of South China, representing its eastern extension to Northeast Japan.

Key words: Capitanian, gastropod, Permian, South China, South Kitakami Belt

Introduction

Occurrences of large Paleozoic gastropods are generally rare (e.g. Rohr *et al.*, 1992), in particular from Permian strata. A well known occurrence was that of *Pleurotomaria*, *Bellerophon*, and an associated large molluscan fauna from the Capitanian (upper Guadalupian) Akasaka Limestone (an accreted mid-oceanic paleo-atoll complex) in Southwest (SW) Japan (e.g. Hayasaka, 1943; Hayasaka and Hayasaka, 1953; Koizumi, 1995; Nützel and Nakazawa, 2012). In addition, another occurrence of a similar molluscan assemblage with a large *Pleurotomaria* was reported from the Balya Maden area in western Turkey (Enderle, 1901); however, its precise fossil locality and stratigraphic position remain unclear. We lately unearthed a specimen of the large gastropod *"Pleurotomaria" yokoyamai*, over 10 cm in diameter, together with two smaller gastropod specimens from the Permian Iwaizaki Limestone representing a continental shelf facies in the South Kitakami Belt, Northeast (NE) Japan (Figure 1). This article reports the first occurrence of a Permian large gastropod from the Iwaizaki Limestone and discusses its geological implications for the paleogeographical position of Permian Japan with respect to South China.

All specimens described in this paper are deposited in the Department of Geology and Paleontology, National Museum of Nature and Science with the acronym NMNS.

Geologic setting

The thick Permian sedimentary package in the South Kitakami Belt is composed mostly of shallow marine terrigenous clastics and carbonates of continental shelf facies (e.g. Choi, 1976; Kawamura *et al.*, 1990). Within the clastics-dominant facies, the middle Permian Iwaizaki Limestone in the southern part of the belt (Figure 1) formed as a patch reef within a mudstone-dominant shelf setting (Kawamura and Machiyama, 1995; Shen and Kawamura, 2001).

Figure 2 depicts the stratigraphic column of the upper part of the Iwaizaki Limestone. Kawamura and Machiyama (1995) subdivided the Iwaizaki Limestone into nine

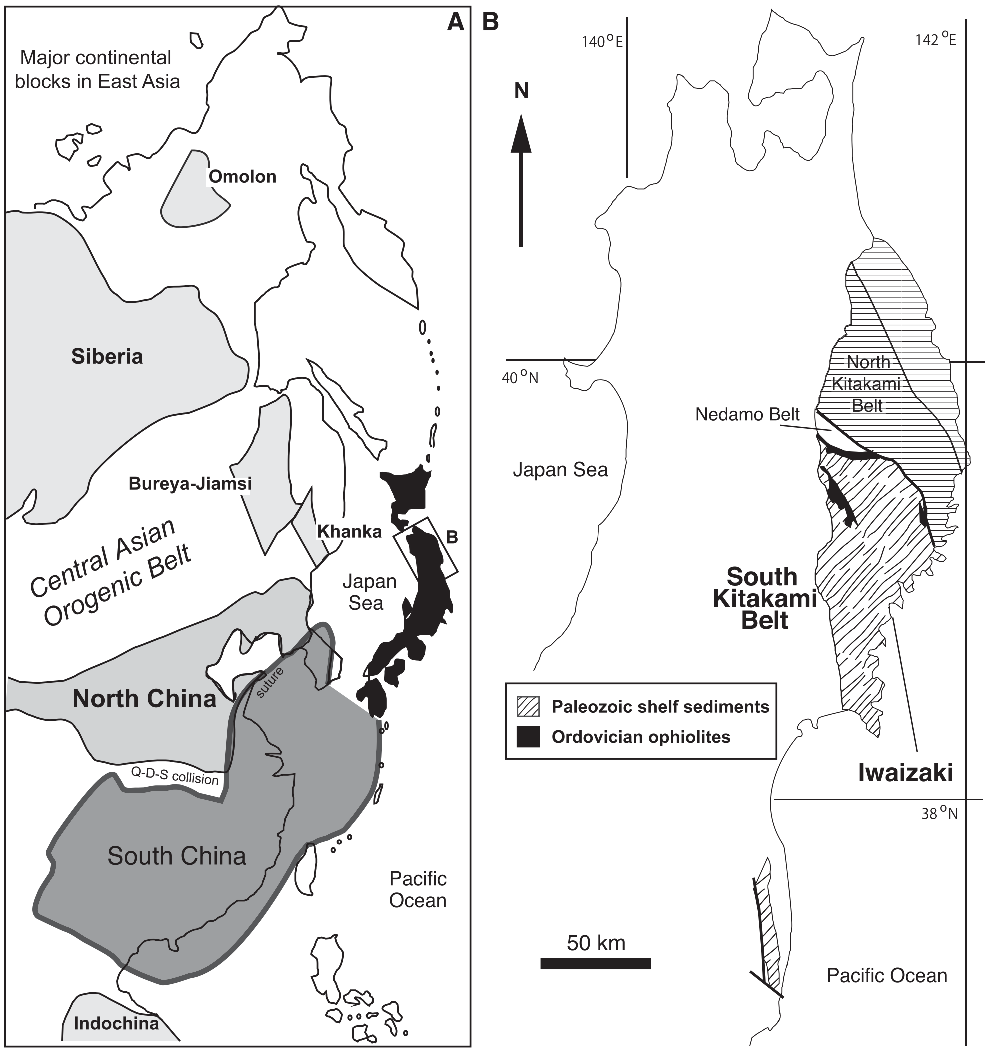

Figure 1. Index map of the Permian Iwaizaki Limestone in NE Japan. **A**, tectonic sketch map of East Asia; **B**, location of the Iwaizaki Limestone in the southern part of the South Kitakami Belt, NE Japan. The South Kitakami Belt is unique in Japan in exposing the Ordovician ophiolites and overlying thick Paleozoic shelf deposits, in which the Permian Iwaizaki Limestone occurs.

units, i.e. Unit 1–9, in ascending order. The lower part (Unit 1) consists of bioclastic limestone interbedded with sandstone, whereas the main part (Unit 2–7) is composed of massive limestone with reef structures. The upper part (Unit 8–9) is composed of well bedded bioclastic limestone and black mudstone. As to the age, the occurrence of the large-tested fusuline *Lepidolina multiseptata* (Morikawa *et al*., 1958; Morikawa, 1960) indicates that the middle-upper parts of the limestone (Units 6, 7, and lower part of Unit 8) belong to the Capitanian (upper Guadalupian). Nonetheless, the topmost 30 m-thick interval, i.e. the upper part of Unit 8 and Unit 9, has not been dated yet due to the absence of index fossils.

Unit 8 is composed of well bedded limestone and mudstone of a lagoonal shelf facies that corresponds to the terminal interval of the patch reef development at Iwaizaki (Kawamura and Machiyama, 1995). The unique gastropods reported here were recovered from two horizons of black mudstone interbedded with limestone in the lower and upper parts of Unit 8, i.e. Horizons M1 and M2, respectively (Figure 2). In addition to the mollusks, these mudstone beds contain abundant, various bioclasts of shallow marine organisms, such as crinoids, calcareous algae, calcisponges, and brachiopods. Horizon M1 yielded one large (*ca*. 11 cm in diameter) gastropod specimen, whereas Horizon M2 provided two smaller ones (less than 3 cm in diameter). The large specimen from Horizon M1 and one of the two small specimens from Horizon M2 are here identified as *"Pleurotomaria" yokoyamai* Hayasaka, and the other small specimen from

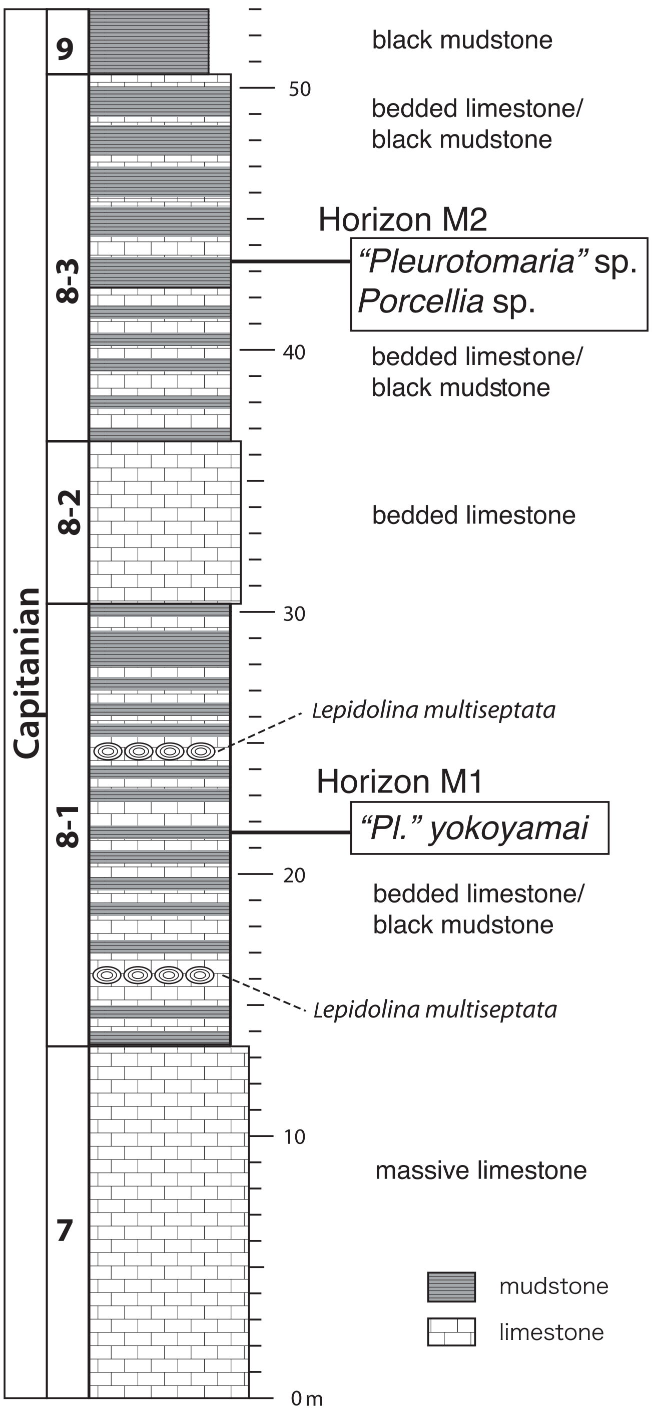

Figure 2. Stratigraphic column of the upper part of the Iwaizaki Limestone with the fossil horizons, Horizons M1 and M2.

Horizon M2 as *Porcellia* sp. Both taxa were not commonly reported from the upper Guadalupian, not only in East Asia but also in the rest of the world.

Paleontological description

Subclass Vetigastropoda
Superfamily Porcellioidea Koken in Zittel, 1895
Family Porcelliidae Koken in Zittel, 1895
Genus *Porcellia* Léveillé, 1835

Porcellia sp.

Figure 3D

Material.—One specimen, NMNS PM25825.

Discussion.—The single insufficient specimen is 22.5 mm in maximum shell diameter and preserves the basal and outer surfaces of the last two whorls. It shows that the preserved last two whorls are almost planispiral, rounded and discoidal. Eight obtuse and thick collabral ribs are present on the basal surface of the preserved last whorl, but there were probably originally 11 or 12 ribs in this whorl altogether because the early one-fourth volution of the whorl was destroyed by sediment compaction. A narrow selenizone, which is represented by a flat surface delimited by two parallel grooves, can be seen in the middle of the outer surface of the whorl. These shell features suggest that NMNS PM25825 is referable to the porcellioidean genus *Porcellia* (s. str.).

Porcellia (s. str.) has a long stratigraphic range from the Early Devonian to late Permian (Frýda *et al.*, 2008), and is a rare element in Permian marine communities. Five species are known so far. *Porcellia nodosa* Hall, 1860 from the lower Permian of Cambodia (Delpey, 1941) is much smaller than NMNS PM25825 and has quite different sculpture that consists of a spiral ridge and sharp collabral ribs. *Porcellia lingshuiensis* Pan, 1985 and *Porcellia magninodosa* Pan, 1985 from the upper Permian of Sichuan Province, South China are 6 mm and 7.5 mm in maximum shell diameter, respectively, which are much smaller values than NMNS PM25825. Additionally, the last whorl is almost smooth in *P. lingshuiensis*, and *P. magninodosa* has almost half the number of collabral ribs of NMNS PM25825. *Porcellia paucituberculata* Pan and Erwin, 2002 from the upper Permian of Guangxi Province, South China bears almost the same number of collabral ribs as NMNS PM25825, but the shell size is also much smaller.

We suggest that NMNS PM25825 is most close to *Porcellia puzoidea* Hayasaka, 1955 from the middle Permian part of the Akasaka Limestone in SW Japan. *P. puzoidea* is the largest species among the Permian species, reaching 35 mm in shell diameter, and bears 17 to 18 collabral ribs in the basal surface of the last whorl (Hayasaka, 1955). Although the number of ribs is slightly smaller, the possibility that NMNS PM25825 is referable to *P. puzoidea* cannot be ruled out. However, this assignment is difficult because the specimens are all poorly preserved and very few in number.

Superfamily Eotomarioidea Wenz, 1938
Family Eotomariidae Wenz, 1938

"*Pleurotomaria*" *yokoyamai* Hayasaka, 1943

Figure 3A–3C.

Pleurotomaria yokoyamai Hayasaka, 1943, p. 28–32, pl. 2, fig. 1, text-fig. 1.
Bathrotomaria? *yokoyamai* (Hayasaka). Hayami and Kase, 1977, p. 32, pl. 3, figs. 6, 7.
"*Pleurotomaria*?" *yokoyamai* Hayasaka. Koizumi, 1995, p. 104, pl. B; pl., C, fig. 1; pl. 27 figs. 1, 2.
Zhonghuaspira yokoyamai (Hayasaka). Nützel and Nakazawa, 2012, p. 111–113, figs. 8P–Q, 9A.

Material.—Two specimens, NMNS PM25823 and NMNS PM25824.

Discussion.—NMNS PM25823 is a poorly preserved specimen, yet some morphological characters useful for identification are still observable. Owing to sediment compaction, the shell is much compressed axially. The shell attains at least 110 mm in width and consists of three steplike whorls that are angulated slightly above the mid-whorl, with a gently inclined broad upper whorl surface and a steeply inclined and concave outer whorl surface. The suture is addressed, and the subsutural portion of the whorl forms a thick and roundly convex spiral band that bears many short and blunt axial ribs. The upper and outer whorl surfaces are ornamented with sharp and fine spiral cords that are approximately 15 and 12 in number, respectively. Some finer spiral cords can be seen in the interspaces of the major spiral cords, but these spiral cords are difficult to count exactly due to the poor state of preservation. The growth lines are not observable. The shell base is smashed by the sediment compaction, but the partly preserved portion opposite to the aperture reveals that the base is smooth. The basal periphery and the shell base appear to have been originally more rounded and convex than indicated by the specimen. In addition to the large shell size, the shell characters described above well fit with those of "*Pleurotomaria*" *yokoyamai* Hayasaka, 1943 from the Permian Akasaka Limestone of Gifu, central Japan, so that NMNS PM25823 can be assigned to that taxon. NMNS PM25824 is a dorso-ventrally compressed, poorly preserved specimen and does not preserve any surface sculpture. This specimen appears to be a juvenile form of this species.

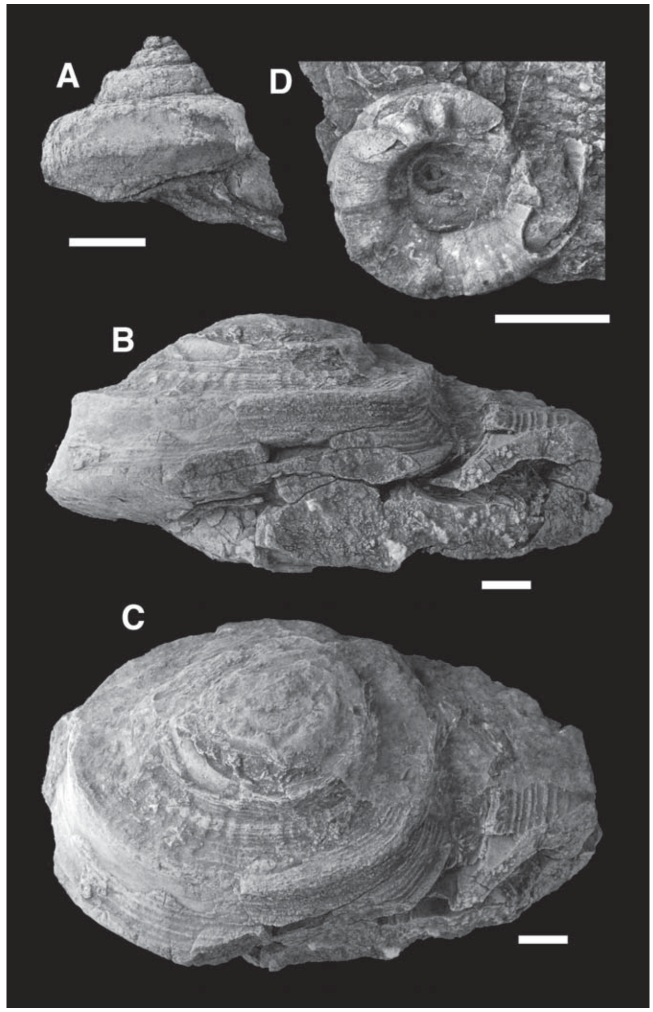

Figure 3. Photographs of the Capitanian gastropods from the Iwaizaki Limestone in the South Kitakami Belt. **A–C**, *"Pleurotomaria" yokoyamai* Hayasaka; A, juvenile specimen (NMNS PM25824) from Horizon M2; B, C, large specimen (NMNS PM25823) from Horizon M1; **D**, *Porcellia* sp. (NMNS PM25825) from Horizon M2. Scale bar is 1 cm.

"*Pleurotomaria*" *yokoyamai* is a remarkable species in its huge shell size among the Paleozoic gastropods and had been known only from the Permian Akasaka Limestone in SW Japan (Hayasaka, 1943). The systematic position of this species remained uncertain mainly due to lack of knowledge about whether the shell bears a selenizone or not. Hayasaka (1943) considered that the selenizone is located at the shouldered edge of the whorl, although he could not detect this structure. Koizumi (1995) on the other hand stated that the shell does not have a slit, and then allocated this species to Trochonematidae without generic assignment. Recently, Nützel and Nakazawa (2012) assigned this species to the genus *Zhonghuaspira* Pan and Erwin, 2002 of Eotomariidae based on the similarity of shell shape and sculpture to the type species of the genus, *Zhonghuaspira gibbicircelloides* (Wang, 1982), from the upper Permian of South China.

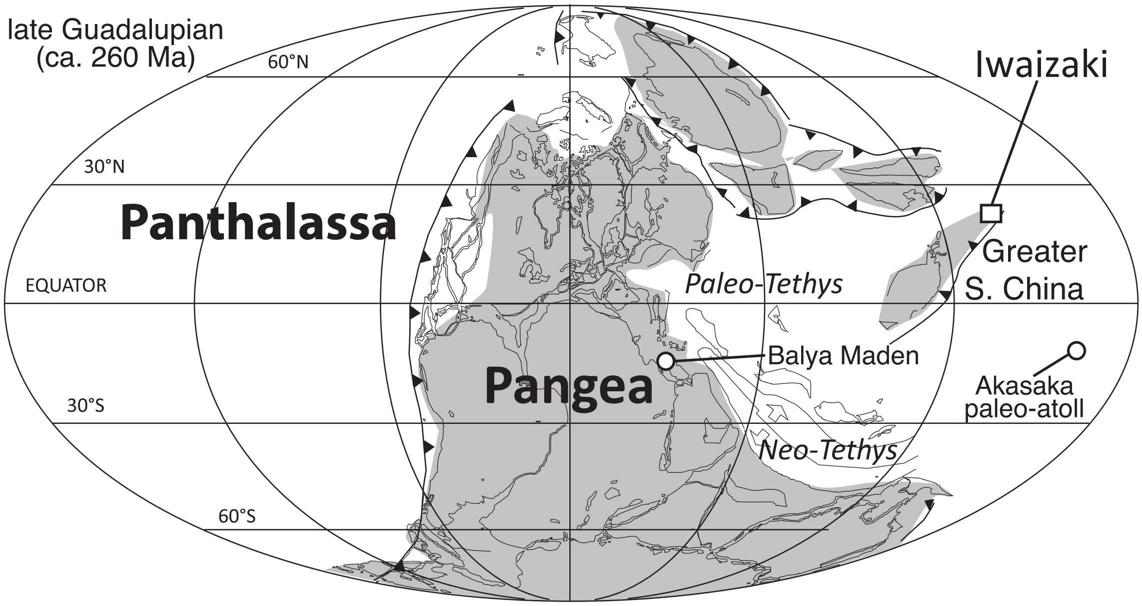

Figure 4. Middle Permian paleogeography (modified from Maruyama *et al.*, 1989 and Scotese, 2008), and possible paleo-position of the South Kitakami Belt on the eastern extension of South China (after Isozaki *et al.*, 2014). Note that the three localities of the unique Permian large gastropod fauna with *"Pleurotomaria"*, i.e., Iwaizaki (this study), Akasaka (Hayasaka, 1943), and Balya Maden in western Turkey (Enderle, 1901), were restricted to low-latitude domains during the Permian.

The second author (TK) has recognized the presence of a narrow and concave selenizone in a specimen of "*Pl.*" *yokoyamai* housed in the National Museum of Nature and Science, although the depth of the labral slit is unknown. We agree with Nützel and Nakazawa (2012) in assigning this species to Eotomariidae, but we consider that it does not belong to the genus *Zhonghuaspira* but most probably to a new genus, because the umbilicus is closed or slitlike and surrounded by a weakly raised funicle, and the shell base is smooth. Here, we maintain this species in its original generic placement because the proposal of a new genus is beyond the scope of this paper.

Discussion

The present occurrence of *"Pleurotomaria"* and *Porcellia* marks their first records not only from the Iwaizaki Limestone but also from the South Kitakami Belt in NE Japan. Their occurrence from the Permian has been extremely rare to date, nonetheless, the present finding has interesting paleobiogeographic implications.

It is noteworthy that a similar fauna was reported from the Akasaka Limestone in SW Japan. The Akasaka Limestone is widely known for the occurrence of a uniquely large-sized gastropod fauna (Hayasaka, 1943; Hayasaka and Hayasaka, 1953; Ozaki, 1968; Koizumi, 1995; Isozaki and Aljinovic, 2009; Nützel and Nakazawa, 2012), including not only "*Pl.*" *yokoyamai* but also other large-sized mollusks, such as *Bellerophon*, *Naticopsis*, *Trachyspira*, *Pseudophorus*, *Akasakiella* (gastropods), and *Shikamaia* (an alatoconchid bivalve). Previous geological analyses clarified that the Akasaka Limestone represents an allochthonous block within the Jurassic accretionary complex of the Mino-Tanba Belt in SW Japan (Isozaki, 1997; Zaw Win, 1999; Isozaki and Ota, 2001; Ota and Isozaki, 2006). The Akasaka Limestone originated in a paleo-atoll complex deposited on a paleo-seamount in the low-latitude superocean of Panthalassa (Figure 4), secondarily was transported northward by the plate motion, and was consequently accreted to the Jurassic continental margin of Japan (South China) (e.g. Kasuya *et al.*, 2012; Kofukuda *et al.*, 2014). The gastropod fauna thus provides paleoenvironmental information for the Permian mid-Panthalassa but tells us nothing about Permian Japan *per se*.

In contrast, the Iwaizaki Limestone represents a remnant of an ancient patch reef developed on a terrigenous clastic-dominant continental shelf (Kawamura and Machiyama, 1995; Shen and Kawamura, 2001). The above-mentioned faunal similarity between the two limestones suggests that the Iwaizaki patch reef was deposited on a continental shelf likewise in a low-latitude domain (Figure 4). The sole difference between the

Iwaizaki and Akasaka limestones exists in different dominant large-tested fusulines; i.e. *Lepidolina* in Iwaizaki versus *Yabeina* in Akasaka. This contrast has been explained as different Permian fusuline territories within the same warm low-latitude mid-Panthalassa (Kasuya *et al.*, 2012).

The other occurrence of "*Pleurotomaria*" from western Turkey (Enderle, 1901) is also concordant with the low-latitude derivation in the western Tethys (Figure 4). The large gastropod "*Pleurotomaria*", together with *Bellerophon* and *Murchisonia*, was reported from a black fusuline-bearing gastropod limestone from the Balya Maden area. The large gastropods were unearthed from the old fossil locality name "Hadji Veli Oglou" in the area; however, its precise locality and the relevant stratigraphic position cannot be confirmed at present. According to a personal communication from Dimir Altiner (Middle East Technical University, Ankara), however, the host Paleozoic limestone in that area is restricted to exotic blocks within the Upper Triassic Karakaya complex (Leven and Okay, 1996; Vachard and Argyriadis, 2002). The age of the fossil-bearing limestone is assumed to be the middle Permian, most likely the Murgabian–Midian (Wordian–Capitanian), thus is essentially the same as the Iwaizaki and Akasaka limestones in Japan.

The geotectonic history of the South Kitakami Belt has been discussed in various ways (e.g. Saito and Hashimoto, 1982; Shi *et al.*, 1995; Tazawa, 1998; Ehiro, 2001; Ueno, 2006). The thick sedimentary package of its Paleozoic shelf strata no doubt originated in a continental margin, and middle to late Paleozoic faunal similarities positively suggest its intimate connection to South China (e.g. Kato, 1990; Nakazawa, 1991; Ehiro, 1997). In this regard, the associated occurrence of a large-tested fusuline (*Lepidolina*) and a rugose coral (*Waagenophyllum*) is particularly noteworthy, because their co-occurrence suggests a warm-water environment under tropical climatic conditions (e.g. Isozaki and Aljinovic, 2009). During the Permian, South China was located on the equator between the Paleo-Tethys and Panthalassa (Figure 4), and developed an extensive carbonate platform enriched in diverse shallow marine fauna of typical Tethyan affinity (e.g. Wang and Jin, 2000).

In accordance, the connection between SW Japan and South China, particularly Cathaysia on its southeast side, was recently supported further by detrital zircon ages of Paleozoic–Mesozoic sandstones in Japan (e.g. Isozaki *et al.*, 2010; Shimojo *et al.*, 2010; Aoki *et al.*, 2012, 2014; Fujisaki *et al.*, 2014). The Silurian and Carboniferous sandstones in the South Kitakami Belt contain *ca*. 700–900 Ma detrital zircon grains whose ages are uniquely identical to the continental crusts of South China but hitherto never reported from North China (e.g. Liu *et al.*, 2008) (Figure 1A). NE Japan likely represents the farthest-east extension of South China, or "Greater South China" (Isozaki *et al.*, 2014; Figure 4). It is noteworthy that the size of South China was much larger than previously believed, and that the Permian continental margin of the South Kitakami belt shared the rare gastropod assemblage with the coeval Akasaka paleo-atoll complex deposited in the mid-Panthalassa and with the Permian limestone in Turkey deposited at the western end of the Paleo-Tethys.

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References

Aoki, K., Isozaki, Y., Kofukuda, D., Sato, T., Yamamoto, A., Maki, K., Sakata, S. and Hirata, T., 2014: Provenance diversification within an arc-trench system induced by the batholith development: the Cretaceous Japan case. *Terra Nova*, vol. 26, p. 139–149.

Aoki, K., Isozaki, Y., Yamamoto, S., Maki, S., Yokoyama, T. and Hirata, T., 2012: Tectonic erosion in Pacific-type orogen: Detrital zircon response to Cretaceous tectonics in Japan. *Geology*, vol. 40, p. 1087–1090.

Choi, D. R., 1976: Distribution of, the Upper Permian fusulinids with relation to limestone lithofacies in the southern Kitakami Mountains, N. E. Japan. *Journal of the Geological Society of Japan*, vol. 82, p. 113–125.

Delpey, G., 1941: Les Gastéropodes Permiens du Cambodge. *Journal de Conchyliologie*, vol. 84, p. 345–369.

Ehiro, M., 1997: Ammonoid palaeobiogeography of the South Kitakami Palaeoland and palaeogeography of eastern Asia during Permian to Triassic time. *In*, Jin, Y. G. and Dineley, D. *eds*., *Palaeontology and Historical Geology (Proceedings of the 30th International Geological Congress*, *vol. 12)*, p. 18–28. VSP International Science Publishers, Utrecht.

Ehiro, M., 2001: Origins and drift histories of some microcontinents distributed in the eastern margin of Asian Continent. *Earth Science (Chikyu-Kagaku)*, vol. 55, p. 71–81.

Enderle, J., 1901: Über eine anthracolithische Fauna von Balia Maaden in Kleineasien. *Beiträge zur Paläontologie und Geologie Österreich-Ungarns und des Orients*, vol. 13, p. 49–109.

Frýda, J., Blodgett, R. B., Lenz, A. C. and Manda, Š., 2008: New porcellioidean gastropods from Early Devonian of Royal Creek area, Yukon Territory, Canada, with notes on their early phylogeny. *Journal of Paleontology*, vol. 82, p. 595–603.

Fujisaki, W., Isozaki, Y., Maki, K., Sakata, S., Hirata, T. and Maruyama, S., 2014: Age spectra of detrital zircon of the Jurassic clastic rocks of the Mino-Tanba AC belt in SW Japan: constraints to the provenance of the mid-Mesozoic trench in East Asia. *Journal of Asian Earth Sciences*, vol. 88, p. 62–73.

Hall, J., 1860: Contributions to the Palaeontology of Iowa, being descriptions of new species of Crinoidea and other fossils. *Geological Report of Iowa*, *Supplement to Vol. 1*, *part 2*, p. 1–92.

Hayami, I. and Kase, T., 1977: A systematic survey of the Paleozoic and Mesozoic Gastropoda and Paleozoic Bivalvia from Japan. *University Museum*, *the University of Tokyo*, *Bulletin*, no. 13, p. 1–155.

Hayasaka, I., 1943: On some gastropods from Kinsyozan, Akasakamati, Gihu Prefecture. *Memoirs of the Faculty of Science*, *Taihoku Imperial University*, *Series 3*, vol. 1, p. 23–46.

Hayasaka, I., 1955: A new Permian species of *Porcellia* from Japan. *Journal of the Faculty of Science*, *Hokkaido University*, *Series 4*, vol. 9, p. 21–24.

Hayasaka, I. and Hayasaka, S., 1953: Fossil assemblages of mollusks and brachiopods of unusually large sizes from the Permian of Japan. *Transactions and Proceedings of the Palaeontological Society of Japan*, *New Series*, no. 30, p. 37–44.

Isozaki, Y., 1997: Jurassic accretion tectonics in Japan. *Island Arc*, vol. 6, p. 25–51.

Isozaki, Y. and Aljinovic, D., 2009: End-Guadalupian extinction of the Permian gigantic bivalve Alatoconchidae: End of gigantism in tropical seas by cooling. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, vol. 284, p. 11–21.

Isozaki, Y., Aoki, K., Nakama, T. and Yanai, S., 2010: New insight into a subduction-related orogen: Reappraisal on geotectonic framework and evolution of the Japanese Islands. *Gondwana Research*, vol. 18, p. 82–105.

Isozaki, Y., Aoki, K., Sakata, S. and Hirata, T., 2014: The eastern extension of Paleozoic South China in NE Japan evidenced by detrital zircon. *GFF*, vol. 136, p. 116–119.

Isozaki, Y. and Ota, A., 2001: Middle/Upper Permian (Maokouan/Wuchiapingian) boundary in mid-oceanic paleo-atoll limestone in Kamura and Akasaka, Japan. *Proceedings of the Japan Academy*, *Series B*, vol. 77B, p. 104–109.

Kasuya, A., Isozaki, Y. and Igo, H., 2012: Constraining paleo-latitude of a biogeographic boundary in mid-Panthalassa: Fusuline province shift on the Late Guadalupian (Permian) migrating seamount. *Gondwana Research*, vol. 21, p. 611–623.

Kato, M., 1990: Paleozoic corals. *In*, Ichikawa, K., Mizutani, S., Hara, I., Hada, S. and Yao, A. *eds*., *Pre-Cretaceous Terranes of Japan*, p. 307–312. Nihon-insatsu, Osaka.

Kawamura, M., Kato, M. and Kitakami Paleozoic Research Group, 1990: Southern Kitakami Terrane. *In*, Ichikawa, K., Mizutani, S., Hara, I., Hada, S. and Yao, A. *eds*., *Pre-Cretaceous Terranes of Japan*, p. 249–266. Nihon-insatsu, Osaka.

Kawamura, T. and Machiyama, H., 1995: A Late Permian coral reef complex, South Kitakami Terrane, Japan. *Sedimentary Geology*, vol. 99, p. 135–150.

Kofukuda, D., Isozaki, Y. and Igo, H., 2014: A remarkable sea-level drop across the Guadalupian–Lopingian (Permian) boundary in low-latitude mid-Panthalassa: Irreversible changes recorded in accreted paleo-atoll limestones in Akasaka and Ishiyama, Japan. *Journal of Asian Earth Sciences*, vol. 82, p. 47–65.

Koizumi, S., 1995: Gastropods. *In*, Hachiya, K. *chief ed*., *The Illustrated Collection of Asami Fossil Museum. Fossils of Kinsyozan*, p. 95–169. Asami Fossil Museum, Gifu. (*in Japanese*)

Léveillé, C., 1835: Aperçu géologique de quelques localités trés riches en coquilles sur les frontiers de France et de Belgique. *Mémoires de la Société Géologique de France*, vol. 2, p. 29–40.

Leven, E. JA. and Okay, A. I., 1996: Foraminifera from the exotic Permo-Carboniferous limestone blocks in the Karakaya complex, northwestern Turkey. *Rivista Italiana di Paleontologiia e Stratigrafia*, vol. 102, p. 139–174.

Liu, X. M., Gao, S., Diwu, C. R. and Ling, W. L., 2008: Precambrian crustal growth of Yangtze craton as revealed by detrital zircon studies. *American Journal of Science*, vol. 308, p. 421–468.

Maruyama, S., Liou, J. G. and Seno, T., 1989: Mesozoic and Cenozoic evolution of Asia. *In*, Ben-Avraham, Z. *ed.*, *Evolution of the Pacific Ocean Margins*, p. 75–99. Oxford Monographs on Geology and Geophysics, Oxford University Press, New York.

Morikawa, R., 1960: Fusulinids from the Iwaizaki Limestone. *Science Reports of the Saitama University*, *Series B*, vol. 3, p. 273–299.

Morikawa, R., Sato, T., Shibazaki, T., Shinada, Y., Okubo, M., Nakazawa, K., Horiguchi, M., Murata, M., Kikuchi, Y., Taguchi, Y. and Takahashi, K., 1958: Stratigraphy and biostratigraphy of the "Iwaizaki Limestone" in the Southern Kitakami mountainland. *In*, *Jubilee Publication in the Commemoration of Professor H. Fujimoto 60th Birthday*, p. 81–90. Kokusai-bunken-insatsu Co., Tokyo.

Nakazawa, K., 1991: Mutual relation of Tethys and Japan during Permian and Triassic time viewed from bivalve fossils. *Proceedings of "Shallow Tethys 3" (Saito Ho-on Kai Special Publication no. 3)*, p. 3–20.

Nützel, A. and Nakazawa, K., 2012: Permian (Capitanian) gastropods from the Akasaka Limestone (Gifu Prefecture, Japan). *Journal of Systematic Palaeontology*, vol. 10, p. 103–169.

Ota, A. and Isozaki, Y., 2006: Fusuline biotic turnover across the Guadalupian–Lopingian (Middle–Upper Permian) boundary in mid-oceanic carbonate buildups: Biostratigraphy of accreted limestone in Japan. *Journal of Asian Earth Science*, vol. 26, p. 353–368.

Ozaki, K., 1968: Problematical fossils from the Permian limestone of Akasaka, Gifu prefecture. *Science Reports of Yokohama National University*, *Section II*, *Biological and Geological Sciences*, no. 14, p. 27–33.

Pan, H. Z. and Erwin, D. H., 2002: Gastropods from the Permian of Guangxi and Yunnan Provinces, South China. *The Paleontologial Society Memoir* 56 *(Journal of Paleontology*, *vol. 76*, *supplement)*, 49 p.

Pan, Y. T., 1985: Fossil Gastropoda from the Permian of Sichuan, Guizhou, Yunnan and Guangxi. *Acta Palaeontologica Sinica*, vol. 21, p. 29–37. (*in Chinese with English abstract*)

Rohr, D. M., Blodgett, R. B. and Furnish, W. M., 1992: *Maclurina manitobensis* (Whiteaves) (Ordovician Gastropoda): The largest known Paleozoic gastropod. *Journal of Paleontology*, vol. 66, p. 880–884.

Saito, Y. and Hashimoto, M., 1982: South Kitakami Region: an allochthonous terrane in Japan. *Journal of Geophysical Research*, vol. 87, p. 3691–3696.

Scotese, C. R., 2008: PALEOMAP Project (http://www.scotese. com).

Shen, J. W. and Kawamura, T., 2001: Guadalupian algal-sponge reefs in siliciclastic environments—the reefs at Lengwu (South China) compared with the reef at Iwaizaki (Japan). *Facies*, vol. 45, p. 137–156.

Shi, G. R., Archbold, N. W. and Zhan, L., 1995: Distribution and characteristics of mixed (transitional) mid-Permian (Late Artinskian–Ufimian) marine faunas in Asia and their paleogeographical

implications. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, vol. 114, p. 241–271.
Shimojo, M., Otoh, S., Yanai, S., Hirata, T. and Maruyama, S., 2010: LA-ICP-MS U-Pb age of some older rocks of the South Kitakami belt, Northeast Japan. *Journal of Geography (Chigaku Zasshi)*, vol. 119, p. 257–269. (*in Japanese with English abstract*)
Tazawa, J., 1998: Pre-Neogene tectonic divisions and Middle Permian brachiopod faunal provinces of Japan. *Proceedings of the Royal Society of Victoria*, vol. 110, p. 281–288.
Ueno, K., 2006: The Permian antitropical fusulinoidean genus *Monodiexodina*: distribution, taxonomy, paleogeography and paleoecology. *Journal of Asian Earth Sciences*, vol. 26, p. 380–404.
Vachard, D. and Argyriadis, I., 2002: Quelques problèmes de biostratigraphie dans le Permien mésogéen, des Alpes Carniques à la Turquie. *Mémoire de l'Association des Géologiques du Permien. Livre à la Mémoire de Nadege Toutin*, vol. 2, p. 75–93.
Wang, H. J., 1982: Late Permian gastropods from Heshan of Laibin, Quangxi Province. *Acta Palaeontologica Sinica*, vol. 21, p. 491–496. (*in Chinese with English abstract*)
Wang, Y. and Jin, Y. G., 2000: Permian paleogeographic evolution of the Jiangnan basin, South China. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, vol. 160, p. 35–44.
Wenz, W., 1938: Gastropoda. Teil 1: Allgemeiner Teil und Prosobranchia. *In*, Schindewolf, O. H. *ed*., *Handbuch der Paläozoologie*, Band 6, Lieferung 1, p. 1–240. Gebrüder Borntraeger, Berlin.
Zaw Win, 1999: Fusuline biostratigraphy and paleontology of the Akasaka Limestone, Gifu Prefecture, Japan. *Bulletin of Kitakyushu Museum of Natural History*, no. 18, p. 1–17.
Zittel, K. A. von. 1895: *Grundzüge der Paläontologie* (*Paläozoologie*), *Abteilung 1*, *Invertebrata*, 971 p. Oldenbourg, München and Leipzig.