First Record of a Primitive Radiolitid Rudist from Japan

Authors: Sano, Shin-Ichi, and Masse, Jean-Pierre

Source: Paleontological Research, 17(4) : 317-324

Published By: The Palaeontological Society of Japan

URL: https://doi.org/10.2517/1342-8144-17.4.317

Paleontological Research, vol. 17, no. 4, pp. 317–324, October 1, 2013

doi:10.2517/1342-8144-17.4.317

First record of a primitive radiolitid rudist from Japan

SHIN-ICHI SANO[1] AND JEAN-PIERRE MASSE[2]

[1]*Fukui Prefectural Dinosaur Museum, Katsuyama, Fukui 911-8601, Japan (e-mail: ssano@dinosaur.pref.fukui.jp)*
[2]*CEREGE, Aix-Marseille Université, Centre St Charles, 13331 Marseille Cedex 03, France (e-mail: masse@cerege.fr)*

Received September 22, 2012; Revised manuscript accepted March 9, 2013

Abstract. A radiolitid rudist, *Eoradiolites* cf. *gilgitensis* is described from a late early to late Aptian shallow-marine limestone block in the lower part of the Yezo Group, central Hokkaido, northern Japan. The Hokkaido *Eoradiolites* is characterized by a compact (non-cellular) outer shell layer, as seen in *E. gilgitensis* (from Iran, Afghanistan, Pakistan, and northern India), *E. griesbachi* (from Afghanistan), and *E. ngariensis* (from western Tibet in China), which are all located in the Southwest Asian region of the northern Tethyan margin. This is one of the earliest records in the world of primitive radiolitids with a radiolitiform myocardinal arrangement. This finding demonstrates that radiolitids had already expanded to the western Pacific at an early evolutionary stage, and that a faunal connection between the northwestern Pacific region and Southwest Asia existed at least in the late Aptian.

Key words: Aptian, *Eoradiolites*, Hokkaido, palaeobiogeography, radiolitid rudists, Yezo Group

Introduction

The Radiolitidae d'Orbigny, 1847, was the most diverse rudist family in the Late Cretaceous. Radiolitids are generally characterized by the so-called 'radiolitiform myocardinal arrangement' *sensu* Mac Gillavry (1937), as well as a celluloprismatic structure in the outer shell layer (e.g. Skelton and Smith, 2000; Fenerci-Masse *et al*., 2006; Pons and Vicens, 2008). The earliest genus of this family is the Hauterivian–early Aptian *Agriopleura* Kühn, 1932, formerly assigned to the Monopleuridae (e.g. Masse and Philip, 1974) but presently placed in the Radiolitidae (Skelton, 2013), although it had not yet fully developed typically radiolitiform pediculate myophores, nor a celluloprismatic structure. Recently, the evolutionary history of primitive radiolitid rudists in the late Aptian–Albian, especially the development of celluloprismatic structure, was addressed by the description of *Archaeoradiolites* Fenerci-Masse, Masse, Arias and Vilas, 2006, of early late Aptian age. The foremost genus in the late late Aptian–Albian was *Eoradiolites* Douvillé, 1909, and other genera, namely *Sphaerulites* Lamarck, 1819 and *Praeradiolites* Douvillé, 1902, are only Late Cretaceous radiolitids (Fenerci-Masse *et al*., 2006; Masse *et al*., 2007).

The distribution of upper Aptian radiolitid rudists was summarized by Masse and Gallo Maresca (1997). Atypical *Eoradiolites* with a compact (non-cellular =acellular) outer shell layer, e.g. *E. gilgitensis* (Douvillé, 1926b), *E. griesbachi* (Douvillé, 1926a), and *E. ngariensis* (Yang *et al*., 1982), flourished only in Southwest Asia (Iran, Afghanistan, Pakistan, northern India, and western Tibet in China). Despite the dissimilarities of the shell structure in the outer shell layer, a monophyletic origin for Mediterranean and Southwest Asian *Eoradiolites* species was accepted based on the similarities of their morphologies, including the presence of outward-facing, pediculate myophores in the left (upper) valve ('radiolitiform arrangement'), the ligamental ridge, and the radial bands. However, significant vicariance between the Southwest Asian and Mediterranean bioprovinces at that time was also illustrated.

Recently, *E.* cf. *gilgitensis*, which is an *Eoradiolites* with a compact outer shell layer, was discovered in a block of uppermost lower to upper Aptian shallow-marine limestone in the lower part of the Yezo Group, central Hokkaido, northern Japan. This discovery is one of the earliest records in the world of primitive radiolitids with a radiolitiform myocardinal arrangement. This report has a strong bearing on the mode of global geographic dispersion of the Radiolitidae.

Geological setting

Eoradiolites cf. *gilgitensis*, described herein, was discovered in a limestone body (olistolith) along the Nibantaki River in the Soshubetsu area, which is in the Hidaka Mountains, central Hokkaido, northern Japan (Figure 1). This locality (42°58′20″N, 142°30′41″E) is equivalent to the Nibantakisawa locality by Sano (2000) and Loc. 5 by Takashima *et al*. (2007). The limestone body contains abundant orbitolinid tests, corals, rudists (a radiolitid and a large requieniid), a nerineacean gastropod (*Adiozoptyxis hidakensis* (Fukada, 1953)), and a solenoporacean alga, a biological assemblage considered to be shallow-marine in origin (Sano, 2000).

The *Eoradiolites*-bearing limestone olistolith is intercalated in the olistostrome or 'slump body' of the lower part of the Yezo Group, a forearc basin deposit in Hokkaido on the northwestern Pacific margin (Sano, 1995, 2000; Kawamura *et al*., 1999; Takashima and Nishi, 1999; Takashima *et al*., 2004). Although no age-diagnostic fossils have been found near the locality, this limestone-bearing olistostrome bed is usually correlated with the Kirigishiyama Olistostrome Member of the Shuparogawa Formation in the Yubari Mountains, central Hokkaido, which is the main depositional area of the Yezo Group (Sano, 1995, 2000; Takashima *et al*., 1997; Takashima and Nishi, 1999). Recently, Iba *et al*. (2011b) reviewed orbitolinid records of shallow-marine limestone blocks, redeposited as olistoliths in the Shuparogawa Formation in the Yubari Mountains, and concluded that the constituent limestone was probably deposited originally during the late early to late Aptian. Their conclusions were based on the presence of *Praeorbitolina* cf. *wienandsi* Schroeder, 1964 (late early Aptian), *Mesorbitolina parva* (Douglass, 1960) (late early Aptian–late Aptian in Cherchi and Schroeder (2013)), and *M. texana* (Roemer, 1849) (late Aptian–Albian) found in the limestone bodies. Iba *et al*. dated the olistostrome bed to the late Aptian based on a detailed bio- and chemostratigraphical correlation of the lower to middle part of the Yezo Group made by Ando and Kakegawa (2007). Herein, therefore, the original depositional time of the radiolitid-bearing limestone is tentatively considered to be of late early to late Aptian age.

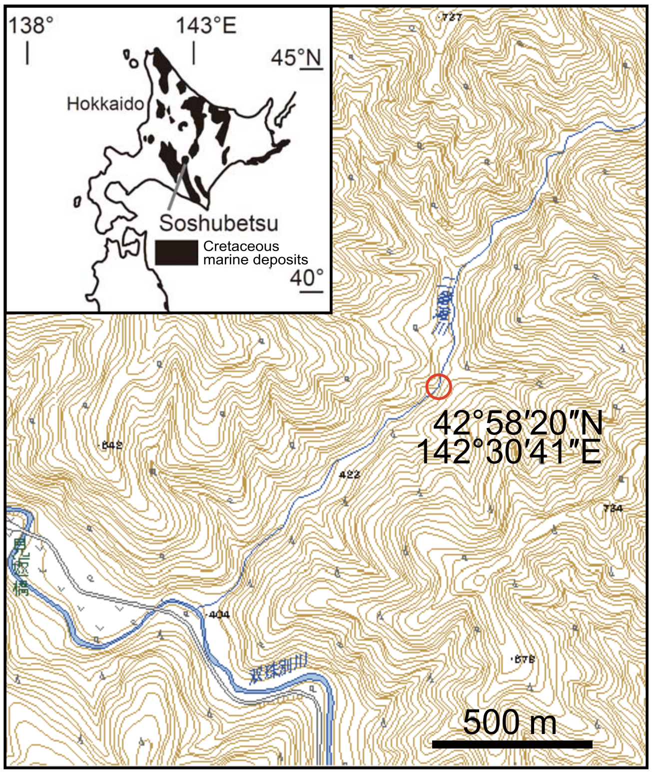

Figure 1. Locality map of *Eoradiolites* cf. *gilgitensis* from a limestone block beside the Nibantaki River in the Soshubetsu area, Hidaka Mountains, central Hokkaido, northern Japan. A 1:25,000 scale topographic map 'Soshubetsuko' published by the Geographical Survey Institute of Japan.

Systematic description

Family Radiolitidae d'Orbigny, 1847
Genus ***Eoradiolites*** Douvillé, 1909
Eoradiolites* cf. *gilgitensis (Douvillé, 1926b)

Figure 2

Material.—Single right valve with a small part of the left valve (Figure 2B) on the slab and several incomplete shells collected from the limestone block beside the Nibantaki River in the Soshubetsu area, Hidaka Mountains, central Hokkaido, northern Japan. Field photos of several randomly oriented sections of right valves were taken at the same locality.

Description.—*External characters*. Right valve with a subcylindrical to conical shape (Figure 2D–F), and left valve possibly slightly convex (Figure 2B). Moderate in size. The antero-posterior commissural diameter of the right valve goes up to about 40 mm, but is usually less than 25 mm (Figure 2); it is larger in conical specimens than in subcylindrical ones. The shell height varies and reaches at least 50 mm in subcylindrical specimens (Figure 2F). The transverse shell outline varies from elliptical (dorso-ventrally elongated) to subrounded to subquadrangular (Figure 2). A longitudinal median depression marks the ligamental groove on the dorsal side of the right valve (Figure 2B, C). Radial bands are well defined in the ventral part of the right valve: the anterior band is moderately salient with a flattened outer face, followed by a depressed interband flanking a salient rounded to flattened posterior band (Figure 2A–C). An antero-ventral carina on the right valve is also distinct and moderately protruding (Figure 2A–C). Growth laminae of the right

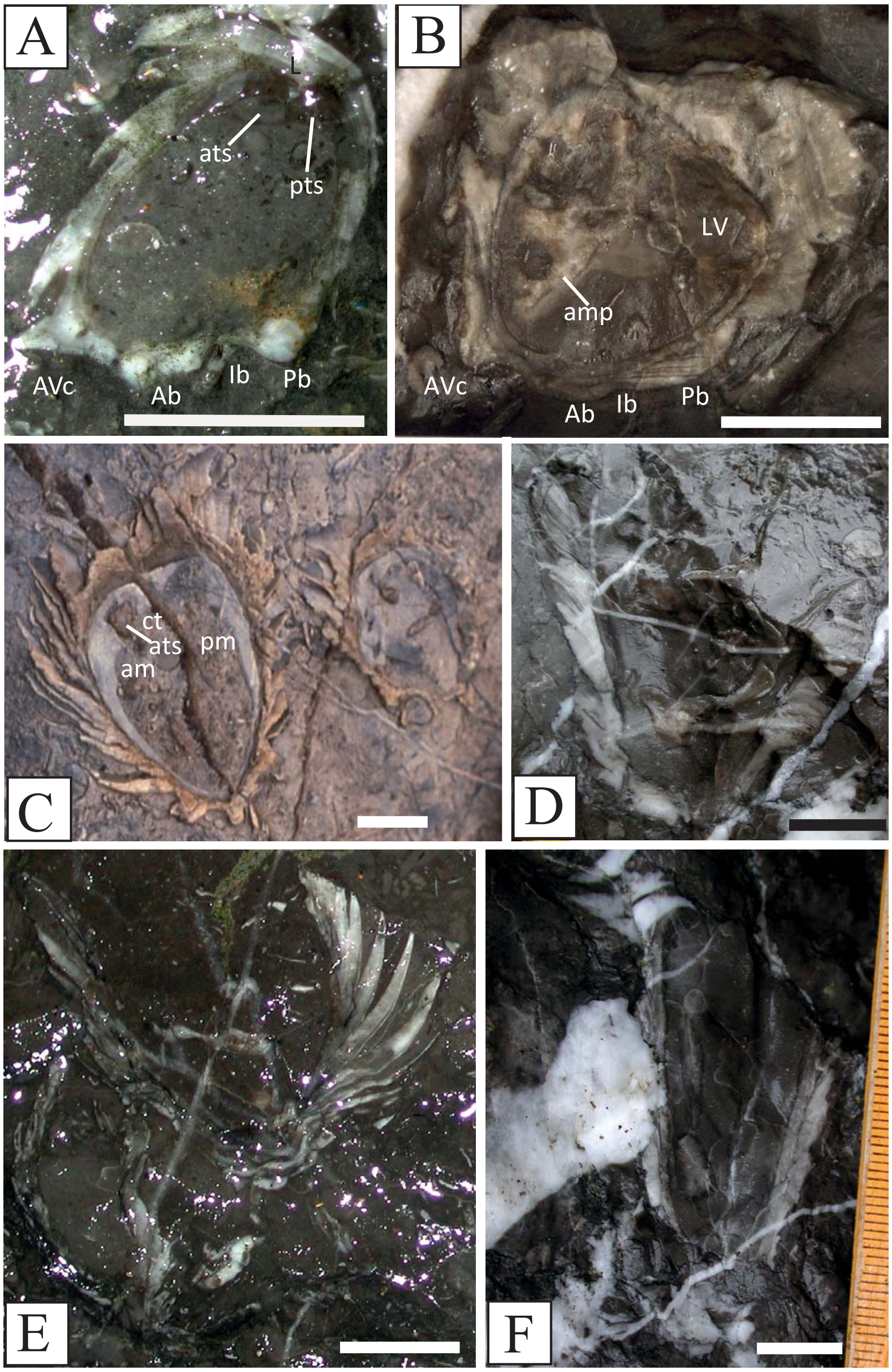

Figure 2. *Eoradiolites* cf. *gilgitensis* from a limestone block beside the Nibantaki River in the Soshubetsu area, Hidaka Mountains, central Hokkaido, northern Japan. Scale bar = 10 mm. **A**, natural transverse section of the right valve (RV). Outcrop photograph. Adapical view. Note a ligamental ridge (L) and a cardinal part: anterior tooth socket (ats) and posterior tooth socket (pts) inside the shell. Radial bands (anterior band (Ab), posterior band (Pb), and interband (Ib)) and anteroventral carina (AVc) are observed in the ventral part of the shell. **B**, RV interior on the weathered surface. Left valve (LV) is preserved *in situ* in the posterior and possibly antero-dorsal parts. Adapical view. Anterior myophoral plate (amp) of LV remains inside the right valve. Radial bands and AVc of RV are also observed. **C**, RV on the weathered surface. Outcrop photograph. Note anterior tooth socket (ats), anterior myophore (am), and ligamental ridge (L) inside the shell, and inflated outer shell layer. **D**, natural longitudinal section of RV showing a conical shape. Outcrop photograph. **E**, natural longitudinal section of RV showing the foliated shell habit. Outcrop photograph. **F**, natural longitudinal section of RV showing a cylindrical shape. Outcrop photograph.

valve are inclined inward and oblique to the shell axis (Figure 2D–F), and tiering or foliation separated by constrictions develops in some individuals (Figure 2C, E). The outer shell layer of the right valve, consisting of a compact shell structure, is moderately thick, up to 10 mm thick in the dorsal and foliated parts, and the inner shell layer is usually thin (Figure 2).

Internal characters. The cardinal apparatus of the right valve includes two sockets, with the anterior being larger than the posterior (Figure 2A), and a central tooth that is short and relatively broad (Figure 2A, C). The anterior myophoral plate on the left valve, showing an anteriorly arched crescentic shape in transverse outline, protrudes into the right valve (Figure 2B). The anterior and posterior myophores on the right valve are situated on the inner shell layer flanking the tooth sockets (Figure 2C). The ligament ridge is short and triangular (Figure 2A).

Discussion.—The present specimens shows a typical radiolitiform myocardinal arrangement, i.e., a crescentic array of subequal teeth and outward-facing, pedunculate myophores (e.g. Skelton and Smith, 2000; Skelton, 2013), and thus are distinguished from *Agriopleura* by the presence of well-developed pedunculate myophoral plates in the left valve, and also by the apparent absence (based on two specimens) of a ligament cavity in the right valve. Inwardly inclined growth laminae, as well as salient and flattened anterior and posterior bands in its right valve, are some of the diagnostic features of the genus *Eoradiolites* (Figure 3B, C) (e.g. Douvillé, 1909, 1910; Masse *et al*., 2007; Pons *et al*., 2010). The foliated outer shell habit of the Hokkaido *Eoradiolites* is also recognized in some other *Eoradiolites* species, such as *E. jumillensis* Masse *et al*., 2007 from Spain and certain *E. gilgitensis* specimens from the Teheran region, Iran (Figure 3A, B).

A compact shell structure in the outer shell layer of its right valve is atypical for the Radiolitidae, and it is unusual for *Eoradiolites* species in the Mediterranean and American regions (e.g. Masse and Gallo Maresca, 1997; Alencáster and García-Barrera, 2008; Pons *et al*., 2010). In contrast, certain Southwest Asian *Eoradiolites* species of late Aptian–Albian age, such as *E. gilgitensis*, *E. griesbachi*, and *E. ngariensis,* have a compact shell structure (e.g. Masse and Gallo Maresca, 1997; Scott *et al*., 2010). The close similarity or synonymy of *E. gilgitensis* and *E. ngariensis* has been mentioned frequently (Pudsey *et al*. 1985; Masse and Gallo Maresca, 1997; Scott *et al*., 2010). However, *E. ngariensis* possesses a wavy shell structure in its outer shell layer corresponding externally to longitudinal rounded 'ribs', whereas *E. gilgitensis* lacks such a structure. In addition, a new specimen of *E. ngariensis* from Kandahar region, Afghanistan (J.-P. M. collection, Université de Provence, Laboratoire de Géologie, specimen no. JPMA 17516), formerly regarded as *Praeradiolites*? sp. (Masse and Gallo Maresca, 1997; fig. 2a), has a strongly convex upward upper valve (J.-P. M., personal observation). In contrast, the shape of the upper valve of *E. gilgitensis* is not well known. However, Mathur and Vogel (1988, pl. 2, fig. 3) showed that the upper valve of *E. gilgitensis* is not strongly convex. Thus *E. gilgitensis* and *E. ngariensis* are not identical and can be considered as distinct species. Because the Hokkaido *Eoradiolites* appears to lack both longitudinal ribs and a greatly convex left valve, it is more similar to *E. gilgitensis* than to *E. ngariensis.* Furthermore, the close similarity but also some differences between *E. gilgitensis* and *E. griesbachi* have been mentioned (Masse and Gallo Maresca, 1997; Scott *et al*., 2010). However, they did not synonymize these two species, probably because of the uncertainty of the age of *E. griesbachi* and the lack of information on its intraspecific variation. Although we cannot rule out the synonymy of these two species, a reclassification of *E. gilgitensis* and *E. griesbachi* will be set aside for future research.

The central tooth of *E. gilgitensis* is long and narrow, and that of *E. griesbachi* is short and narrow (Scott *et al*., 2010). In contrast, that of the Hokkaido *Eoradiolites* is short and relatively broad. The ligament ridge of *E. gilgitensis* is thick and prominently forked at its inner end (Pudsey *et al*., 1985), whereas Scott *et al*. (2010) pointed out the ligament ridge of *E. gilgitensis*, *E. griesbachi*, and *E. ngariensis* changes from planar to bulbous in shape towards the commissure. However, the shape of the ligament ridge changes depending on the positions of the transverse sections away from the commissure (e.g. Masse and Gallo Maresca, 1997). The ligament ridge of the Hokkaido form is short and triangular. However, variation in the form of the ligament ridge and the central tooth of *E. gilgitensis* and its relatives has not been well documented. Furthermore, the lack of information on the left valve and also the outer ornamentation of the shell of the Hokkaido material prevents further comparison with *E. gilgitensis* at present. Because the probable synonymy of several '*Praeradiolites*' species from the Albian of Tibet with *Eoradiolites* has been mentioned (Masse *et al*., 2007; Scott *et al*., 2010), further work is necessary to reveal their taxonomic relationship with Southwest Asian *Eoradiolites* species. Thus the Hokkaido form is assigned to the *E. gilgitensis* group, which includes at least *E. gilgitensis* and *E. griesbachi*, and is tentatively called *Eoradiolites* cf. *gilgitensis* in this paper because *E. gilgitensis* is better defined than *E. griesbachi*. However, it should be noted that *E. griesbachi* has priority over *E. gilgitensis* by page position of the papers describing them, which were published in the same volume of *Records of the Geological Survey*

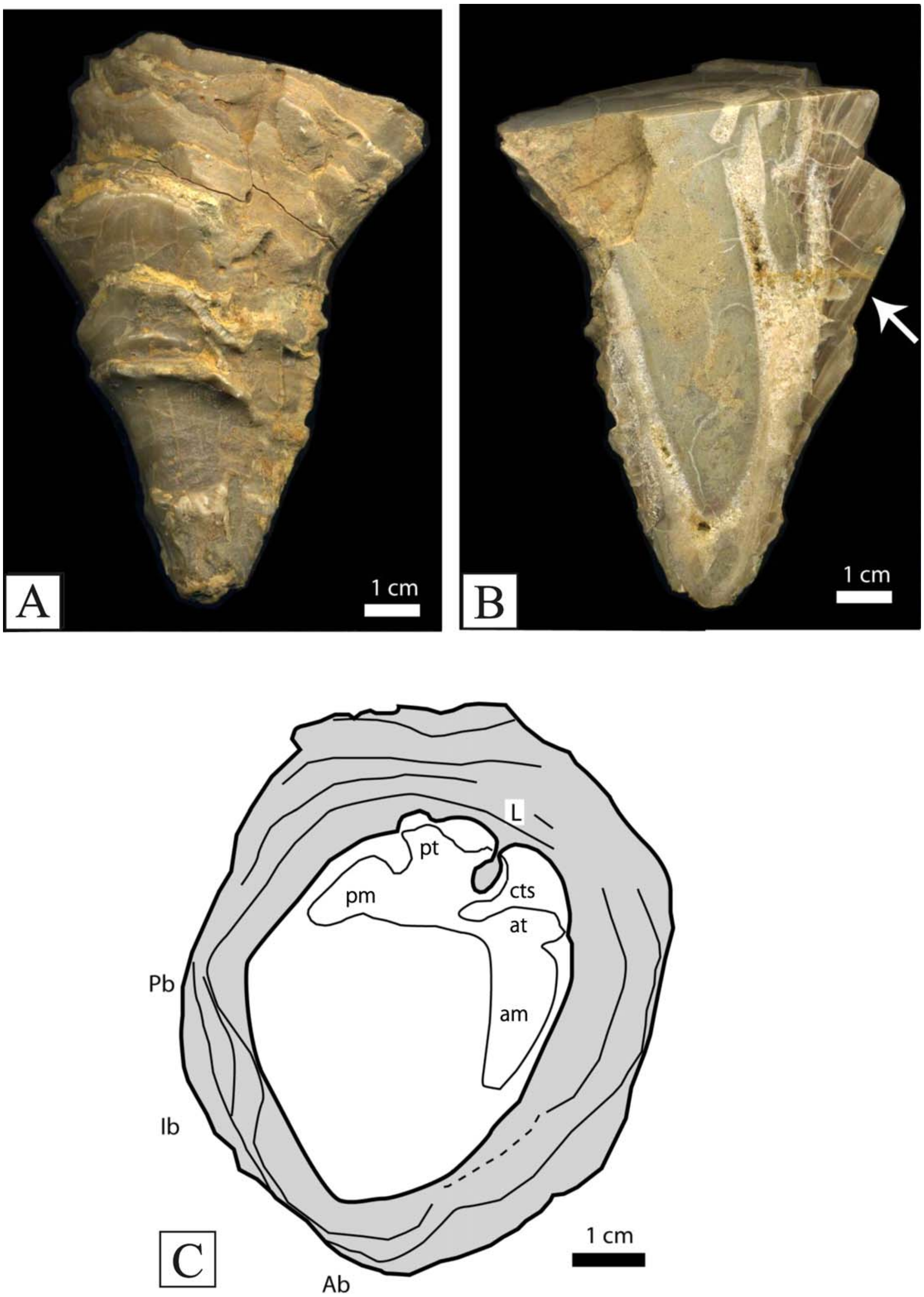

Figure 3. *Eoradiolites gilgitensis* from the Teheran region, Iran (J.-P. M. collection, Université de Provence, Laboratoire de Géologie, specimen no. JPMA 17515) showing its myocardinal organization and ventral bands, which were previously noted by Masse and Gallo-Maresca (1997; fig. 2b). **A**, anterior side of the right valve with a lamellar shell habit; **B**, longitudinal section showing the orientation of growth lines (arrow); **C**, transverse section of the right valve with the myocardinal part of the left valve inside (abumbonal view). Abbreviations: anterior tooth (at), posterior tooth (pt), central tooth socket (cts), anterior myophore (am), posterior myophore (pm), ligamental ridge (L), anterior band (Ab), posterior band (Pb), and interband (Ib).

of India, if these two species are ever synonymized.

Distribution and stratigraphic range.— *E. gilgitensis* has been reported from the late Aptian to Albian in Teheran (Iran), Qandahar and Panjaw (Afghanistan), Gilgit in Kohistan (Pakistan), and Ladakh (northern India) in the Southwest Asian region of the northern Tethyan margin (Douvillé, 1926b; Pudsey *et al*., 1985; Mathur and Vogel, 1988; Masse and Gallo-Maresca, 1997). The age of the probably similar species *E. griesbachi* is not definitive, although it is thought to be late Aptian (Masse and Gallo-Maresca, 1997).

The Hokkaido *E*. cf. *gilgitensis* can be dated broadly to the late early to late Aptian according to the limited geological and biostratigraphical information. Because the appearance of primitive radiolitids with a typical radiolitiform myocardinal arrangement, such as *Archaeoradiolites* and *Eoradiolites*, has been recorded in the early late Aptian in the Mediterranean Tethys, the Hokkaido radiolitid is also possibly assigned to the late Aptian, though further work is necessary to clarify this age assignment more definitively.

Remarks.—The size of *E. gilgitensis* individuals varies at each locality. The sizes of figured specimens from Gilgit in Pakistan (late Aptian–early Albian: Douvillé, 1926b; Pudsey *et al*., 1985) and Teheran in Iran (late Aptian–Albian: Masse and Gallo Maresca, 1997, fig. 2b) are about 5–7 cm in antero-posterior commissural diameter, whereas the specimens from Ladakh in northern India (earliest late Aptian: Mathur and Vogel, 1988) and central Afghanistan (Gargasian (=early late Aptian): Masse and Gallo Maresca, 1997, fig. 1b and Montenat *et al*., 1982, fig. 3) are around 3 cm (up to 5 cm) in commissural diameter. The Hokkaido *Eoradiolites* (possibly late Aptian) is comparable in size to those of the latter group, and significantly smaller than those of the former group. Thus, the change in shell size in *E. gilgitensis* group is assumed and can be considered to be another example of a phyletic size increase, which is recognized in several rudist lineages including *Archaeoradiolites* (e.g. Fenerci-Masse *et al*., 2006).

Palaeobiogeographical implications

The discovery of *E*. cf. *gilgitensis* in Hokkaido provides one of the earliest records of primitive radiolitids with a radiolitiform myocardinal arrangement in the world, and indicates that primitive radiolitids expanded their distribution more widely than previously thought, reaching the northwestern Pacific region in an early stage of their evolution. There are few records of radiolitids in the Pacific. A review of the holotype of *Durania*? *californica* Anderson, 1958 from northern California revealed that it does not belong to a radiolitid rudist (Iba *et al*., 2009), and this specimen is assigned to the caprinuloideid caprinoid *Immanitas anahuacensis* Palmer, 1928 (Sano *et al*., 2013). The occurrence of the radiolitids *Distefanella mooretownensis* (Trechmann, 1924) and *D.* sp. of late Campanian–Maastrichtian age from the Wodejebato Guyot in the central Pacific was mentioned by Premoli Silva *et al*. (1995), but these rudists have not been formally described yet. Thus the finding of a radiolitid in Japan provides presently the first report of this family to be systematically described in the Pacific.

van Waasbergen (1995) mentioned the occurrence of radiolitid fragments in the dredged rocks from western Pacific guyots in several places, with a photomicrograph of a rudist fragment showing a celluloprismatic structure of the radiolitid rudist (p. 491, figure A17). It appears that an Albian age was supposed for these samples. Especially, the photographed specimen was in sediments dated as the late Albian by co-occurring planktonic foraminifers. On the other hand, Swinburne and Masse (1995) pointed out the peculiar absence of radiolitids in the Lower Cretaceous limestone recovered from some guyots in the central Pacific in Ocean Drilling Program (ODP) Leg 143. This observational difference can be explained by the wide range of sedimentary facies that was encountered in the dredged materials compared to the drilling cores recovered during the ODP cruise. On the other hand, *E. gilgitensis* and its related forms have only a compact shell structure instead of a cellular shell structure, and thus cannot be easily recognized in fragments. This property may be another explanation why radiolitid records are rare in cored and dredged material of mid-Cretaceous age in the Pacific. Thus the radiolitid records in the central Pacific should be reassessed in future studies, taking into account the possible occurrence of radiolitids with a compact shell structure.

Masse and Gallo Maresca (1997) summarized the distribution of late Aptian radiolitids, and pointed out the dominance of atypical, non-cellular radiolitids in the Southwest Asian region. They also suggested that there was a vicariance between the Southwest Asian and Mediterranean regions in the Tethyan realm in the late Aptian. The morphological similarity between *E*. cf. *gilgitensis* from Hokkaido and *E*. *gilgitensis* from Southwest Asia clearly suggests a faunal connection between the northwestern Pacific and the 'Southwest Asian Bioprovince (*sensu* Masse and Gallo Maresca, 1997)' of the Tethyan realm, at least in the late Aptian. A corresponding possible sister taxonomic relationship between *Praecaprotina yaegashii* (Yehara, 1920) from northern Japan and *Horiopleura haydeni* Douvillé, 1926b from Gilgit, Pakistan (Skelton and Masse, 1998; Skelton *et al*., 2013) also supports this idea. Thus a unique biogeographic province covering the areas from Southwest Asia to the northwestern Pacific region may have been established in the late Aptian.

It should be noted that other contemporaneous large-scale biogeographical events are also recognized in the Pacific, including the appearance of endemic rudists of the 'Japanese–western Pacific Province (*sensu* Masse and Shiba, 2010)' in the late Aptian–Albian (Masse and Shiba, 2010, Sano *et al*., 2011), the Albian stepwise demise of rudists and other Tethyan biota, and the subsequent establishment of the 'North Pacific Biotic Province' (Iba and Sano, 2007, 2008; Iba *et al*., 2011a, c). Furthermore, the separation of the Mediterranean and Caribbean provinces in the Tethyan realm, probably caused by the formation of the Atlantic (Coates, 1973), started by the early Aptian (Chartrousse and Masse, 2004). Thus a global scale reorganization of rudist palaeobiogeography, i.e., the establishment of several bioprovinces within the Tethyan realm, may have occurred in the Aptian–Albian. This hypothesis and its possible causal mechanism warrant further testing.

Acknowledgements

Thanks are extended to Manabu Kano (Mikasa City Museum, Japan) and Reishi Takashima (Tohoku University Museum, Japan) for their help during the field work, and to Kazushige Tanabe (The University Museum, the University of Tokyo, Japan) for reading an early version of the manuscript, and to Peter W. Skelton (Open University, UK), Robert W. Scott (Precision Stratigraphy Associates and University of Tulsa, U.S.A.) and Yasufumi Iryu (Tohoku University, Japan) for their critical review and useful suggestions.

References

Alencáster, G. and García-Barrera, P., 2008: Albian radiolitid rudists (Mollusca Bivalvia) from East-Central Mexico. *Geobios*, vol. 41, p. 571–587.

Anderson, F. M., 1958: Upper Cretaceous of the Pacific Coast. *Geological Society of America Memoir* 71, 378 p.

Ando, A. and Kakegawa, T., 2007: Carbon isotope records of terrestrial organic matter and occurrence of planktonic foraminifera from the Albian Stage of Hokkaido, Japan: Ocean atmosphere $\delta^{13}C$ trends and chronostratigraphic implications. *Palaios*, vol. 22, p. 417–432.

Chartrousse, A. and Masse, J.-P., 2004: Revision of the early Aptian Caprininae (rudist bivalves) of the New World. Evolutionary and palaeobiogeographic implications. *Courier Forschungsinstitut Senckenberg*, vol. 247, p. 19–34.

Cherchi, A. and Schroeder, R., 2013: The *Praeorbitolina*/*Palorbitolinoides* Association: an Aptian biostratigraphic key-interval at the southern margin of the Neo-Tethys. *Cretaceous Research*, vol. 39, p. 70–77.

Coates, A. G., 1973: Cretaceous Tethyan coral-rudist biogeography related to the evolution of the Atlantic Ocean. *In*, Hughes, N. F. *ed*., *Organisms and Continents through Time*. Special Papers in Palaeontology 12, p. 169–174. Palaeontological Association, London.

d'Orbigny, A. D., 1847: Sur les Brachiopodes ou Palliobranches (deuxième mémoire). *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences*, t. 25, p. 266–269.

Douglass, R. C., 1960: The foraminiferal genus *Orbitolina* in North America. *U. S. Geological Survey Professional Paper 333*, 52 p.

Douvillé, H., 1902: Classification des *Radiolites*. *Bulletin de la Société Géologique de France, Série 4*, t. 2, p. 461–477.

Douvillé, H., 1909: Sur le genre *Eoradiolites* nov. *Bulletin de la Société Géologique de France, Série 4*, t. 9, p. 77.

Douvillé, H., 1910: Études sur les rudistes de Sicile, d'Algérie, d'Égypte, du Liban et de la Perse. *Société Géologique de France, Mémoires*, no. 41, p. 1–84.

Douvillé, H., 1926a: Description de quelques fossiles crétacés de l'Afghanistan. *Records of the Geological Survey of India*, vol. 58, p. 345–348.

Douvillé, H., 1926b: Fossiles recueillis par Hayden dans le Kashmir en 1906 et les Pamirs en 1914; leur description. *Records of the Geological Survey of India*, vol. 58, p. 349–357.

Fenerci-Masse, M., Masse, J.-P., Arias, C. and Vilas, L., 2006: *Archaeoradiolites*, a new genus from the Upper Aptian of the Mediterranean region and the origin of the rudist family Radiolitidae. *Palaeontology*, vol. 49, p. 769–794.

Fukada, A., 1953: A new species of *Nerinea* from central Hokkaido. *Journal of the Faculty of Science, Hokkaido University, Series 4*, vol. 8, p. 211–216.

Iba, Y., Mutterlose, J., Tanabe, K., Sano, S., Misaki, A. and Terabe, K., 2011a: Belemnite extinction and the origin of modern cephalopods 35 m.y. prior to the Cretaceous–Paleogene event. *Geology*, vol. 39, p. 483–486.

Iba, Y. and Sano, S., 2007: Mid-Cretaceous step-wise demise of the carbonate platform biota in the Northwest Pacific and establishment of the North Pacific biotic province. *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 245, p. 462–482.

Iba, Y. and Sano, S., 2008: Paleobiogeography of the pectinid bivalve *Neithea*, and its pattern of step-wise demise in the Albian Northwest Pacific. *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 267, p. 138–146.

Iba, Y., Sano, S. and Miura, T., 2011b: Orbitolinid foraminifers in the Northwest Pacific: Their taxonomy and stratigraphy. *Micropaleontology*, vol. 57, p.163–171.

Iba, Y., Sano, S., Skelton, P. W., Kagi, H. and Tanabe, K., 2009: First record of Late Albian canaliculate rudist from northern California and re-assessment of *Durania*? *californica* Anderson, 1958. *Cretaceous Research*, vol. 30, p. 540–546.

Iba, Y., Sano, S. and Tanabe, K., 2011c: A Tethyan bivalve, *Neithea* (Cretaceous pectinid) from northern California, and its biogeographic implications. *Paleontological Research*, vol. 15, p. 79–84.

Kawamura, M., Ueda, H. and Narushima, T., 1999: Unconformities and slump bodies recognized in forearc sediments—stratigraphic phenomena at the basal part of the Middle Yezo Group, Sorachi-Yezo Belt, central Hokkaido—. *Memoirs of the Geological Society of Japan*, no. 52, p. 37–52. (*in Japanese with English abstract*)

Kühn, O., 1932: *Fossilium Catalogus, I. Animalia, Pars 54, Rudistae*, 200 p. Gustav Feller, Neubrandenburg.

Lamarck, J. B. de, 1819: *Histoire Naturelle des Animaux sans Vertèbres*. vol. 6, p. 230–240. Chez l'auteur, Paris.

Mac Gillavry, H. J., 1937: Geology of the province of Camaguey, Cuba, with revisional studies in rudist paleontology. *Geographis-*

che en geologische Mededeelingen, no. 14, 168 p.

Masse, J.-P., Fenerci-Masse, M., Vilas, L. and Arias, C., 2007: Late Aptian–Albian primitive Radiolitidae (bivalves, Hippuritoidea) from Spain and SW France. *Cretaceous Research*, vol. 28, p. 697–718.

Masse, J.-P. and Gallo Maresca, M., 1997: Late Aptian Radiolitidae (rudist bivalves) from the Mediterranean and Southwest Asiatic regions: taxonomic, biostratigraphic and palaeobiogeographic aspects. *Palaeogeography, Palaeoclimatology, Palaeoecology*, vol. 128, p. 101–110.

Masse, J.-P. and Philip, J., 1974: Définition, position systématique, répartition stratigraphique et évolution du genre *Agriopleura* Kühn (Rudiste). *Géologie Méditerranéenne*, t. 1, p. 53–62.

Masse, J.-P. and Shiba M., 2010: *Praecaprotina kashimae* nov. sp. (Bivalvia, Hippuritacea) from the Daiichi-Kashima Seamount (Japan Trench). *Cretaceous Research*, vol. 31, p. 147–153.

Mathur, N. S. and Vogel, K., 1988: Some rudists from Khalsi Limestone of Indus formation, Ladakh Himalaya. *Geobios*, vol. 21, p. 693–707.

Montenat, C., Moullade, M. and Philip, J., 1982: Le Crétacé inférieur à Orbitolines et Rudistes d'Afghanistan central. *Géologie Méditerranéenne*, t. 9, p. 109–122.

Palmer, R. H., 1928: The rudistids of southern Mexico. *Occasional Papers of the California Academy of Science*, no. 14, 137 p.

Pons, J. P. and Vicens, E., 2008: The structure of the outer shell layer in radiolitid rudists, a morphoconstructional approach. *Lethaia*, vol. 41, p. 219–234.

Pons, J. P., Vicens, E., Chikhi-Aouimeur, F. and Abdallah, H., 2010: Albian *Eoradiolites* (Bivalvia: Radiolitidae) from Jabal Naïmia, Gafsa Region, Tunisia, with revisional studies on the Albian forms of the genus. *Journal of Paleontology*, vol. 84, p. 321–331.

Premoli Silva, I., Nicora, A., Arnaud Vanneau, A., Budd, A. F., Camoin, G. F. and Masse, J.-P., 1995: Paleobiogeographic evolution of shallow-water organisms from the Aptian to the Eocene in the western Pacific. *In*, Haggerty, J. A., Premoli Silva, I., Rack, F. and McNutt, M. K. *eds.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 144, p. 887–893. Ocean Drilling Program, College Station.

Pudsey, C. J., Schroeder, R. and Skelton, P. W., 1985: Cretaceous (Aptian/Albian) age for island-arc volcanics, Kohistan, N. Pakistan. *In*, Gupta, V. J. *ed.*, *Contributions to Himalayan Geology, Vol. 3, Geology of Western Himalayas*, p. 150–168. Hindustan Publishing Corporation, Delhi.

Roemer, F., 1849: *Texas, Mit besonderer Rücksicht auf deutsche Auswanderung und die physischen Verhältnisse des Landes nach eigener Beobachtung geschildert*, 464 p. Marcus, Bonn.

Sano, S., 1995: Lithofacies and biofacies of Early Cretaceous rudist-bearing carbonate sediments in northeastern Japan. *Sedimentary Geology*, vol. 99, p. 179–189.

Sano, S., 2000: Reconstruction of carbonate platform from olistolith embedded in Lower Yezo Group. *Gekkan Chikyu (Earth Monthly)*, Special Issue 29, p. 45–60. (*in Japanese*)

Sano, S., Iba, Y., Skelton, P. W., Aguilar-Pérez, J. and Tanabe, K., 2013: First record of *Immanitas* (Bivalvia, Hippuritoidea) from northern California, U.S.A. *Caribbean Journal of Earth Science*, vol. 45, p. 77–84.

Sano, S., Iba, Y., Skelton, P. W., Masse, J.-P., Aguilar, Y. M. and Kase, T., 2011: New Albian canaliculate polyconitid rudist from the Pacific. *In*, Mitchell, S. F. *ed.*, *The Ninth International Congress on Rudist Bivalves*, *18th to 25th June 2011*, *Kingston*, *Jamaica*, *Abstracts*, *Articles and Field Guides*. *UWI Mona Contributions to Geology*, no. 6, p. 21.

Schroeder, R., 1964: Communication préalable sur l'origine des Orbitolines. *Comptes Rendus de l'Académie des Sciences de Paris*, vol. 10, p. 411–413.

Scott, R. W., Wan, X., Sha, J. and Wen, S., 2010: Rudists of Tibet and the Tarim Basin, China: significance to Requieniidae phylogeny. *Journal of Paleontology*, vol. 84, p. 444–465.

Skelton, P. W., 2013: Rudist classification for the revised Bivalvia volumes of the *Treatise on Invertebrate Paleontology*. *Caribbean Journal of Earth Science*, vol. 45, p. 9–33.

Skelton, P. W. and Masse, J.-P., 1998: Revision of the Lower Cretaceous rudist genera *Pachytraga* Paquier and *Retha* Cox (Bivalvia: Hippuritacea), and the origins of the Caprinidae. *Geobios, Mémoire Spécial*, no. 22, p. 331–370.

Skelton, P. W., Sano, S. and Masse, J.-P., 2013: Rudist bivalves and the Pacific in the Late Jurassic and Early Cretaceous. *Journal of the Geological Society*, vol. 170, p. 513–526.

Skelton, P. W. and Smith, A. B., 2000: Preliminary phylogeny for rudist bivalves: sifting clades from grades. *In*, Harper, E. M., Taylor, J. D. and Crame, J. A. *eds.*, *Evolutionary Biology of the Bivalvia*, Geological Society, London, Special Publications, vol. 177, p. 97–127.

Swinburne, N. H. M. and Masse, J.-P., 1995: Early Cretaceous rudist fauna of Allison and Resolution guyots, Mid-Pacific Mountains. *In*, Winterer, E. L., Sager, W. W., Firth, J. V. and Sinton, J. M. *eds.*, *Proceedings of the Ocean Drilling Program*, *Scientific Results*, vol. 143, p. 3–14. Ocean Drilling Program, College Station.

Takashima, R., Kawabe, F., Nishi, H., Moriya, K., Wani, R. and Ando, H., 2004: Geology and stratigraphy of forearc basin sediments in Hokkaido, Japan: Cretaceous environmental events on the northwest Pacific margin. *Cretaceous Research*, vol. 25, p. 365–390.

Takashima, R. and Nishi, H., 1999: Reevaluation of the intra-Yezo disturbance and the Cretaceous tectonics in Hokkaido, Japan. *Journal of the Geological Society of Japan*, vol. 105, p. 711–728. (*in Japanese with English abstract*)

Takashima, R., Sano, S., Iba, Y. and Nishi, H., 2007: Late Aptian warming recorded in the northwest Pacific margin. *Journal of the Geological Society*, vol. 164, p. 333–339.

Takashima, R., Suzuki, N., Koike, T. and Saito, T., 1997: Reexamination of the unconformity proposed at the boundary between the Lower and Middle Yezo Groups in the Soshubetsu area, Hokkaido, and its geological significance: reevaluation of the intra-Yezo disturbance. *Journal of the Geological Society of Japan*, vol. 103, p. 489–492. (*in Japanese with English abstract*)

Trechmann, C. T., 1924: The Cretaceous limestones of Jamaica and their Mollusca. *Geological Magazine*, vol. 61, p. 385–410.

Waasbergen, R. J. van, 1995: Sediment facies and environments of deposition on Cretaceous Pacific carbonate platforms: an overview of dredged rocks from western Pacific guyots. *In*, Winterer, E. L., Sager, W. W., Firth, J. V. and Sinton, J. M. *eds.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 143, p. 471–493. Ocean Drilling Program, College Station.

Yang, Z., Nie, Z., Wu, S. and Liang, D., 1982: Cretaceous rudists from Ngari, Xizang (Tibet), Autonomous Region, China and their geologic significance. *Acta Geologica Sinica*, vol. 56, p. 293–301. (*in Chinese with English abstract*)

Yehara, S., 1920: A pachyodont lamellibranch from the Cretaceous deposits of Miyako in Rikuchū. *Journal of the Geological Society of Tokyo*, vol. 27, p. 39–44.