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Epidiceras (Bivalvia, Hippuritoidea) from the Tithonian–Berriasian Torinosu-type Limestones of the Sakawa Area, Southwest Japan

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Abstract: Excavated specimens of two primitive rudists, *Epidiceras speciosum* (Goldfuss) and *Epidiceras guirandi* (de Loriol), are systematically described for the first time from the Tithonian–Berriasian Torinosu-type limestones of the Torinosu Group in the Sakawa area, Central Shikoku, Southwest Japan. *E. guirandi* was previously known only from the Late Kimmeridgian Mediterranean Tethys, so this occurrence in Southwest Japan significantly extends the recorded biogeographical and stratigraphical distribution of the species. Moreover, the documentation of *E. speciosum* from the Torinosu-type limestones in Japan and the Bau Limestone in Sarawak, Borneo, indicate that this species was already widespread throughout the Tethyan Realm at that time. Such records of early rudists in the eastern Tethys and the western Pacific enhance our understanding of the early evolutionary history of rudists.

Key Words: *Epidiceras,* rudist, Tithonian–Berriasian, Torinosu-type limestone, Torinosu Group, Southwest Japan

Sakawa Bölgesindeki (Güneybatı Japonya) Titoniyen–Berriasiyen Yaşlı Torinosu Tipi Kireçtaşlarında Saptanan *Epidiceras* (Bivalvia, Hippuritoidea)

Özet: Sakawa bölgesindeki (Orta Shikoku, Güneybatı Japonya) Torinosu Grubu'na ait Titoniyen–Berriasiyen yaşlı Torinosu tipi kireçtaşlarından derlenen *Epidiceras speciosum* (Goldfuss) ve *Epidiceras guirandi* (de Loriol)'ye ait ilkel rudist örnekleri sistematik olarak ilk kez tanımlanmıştır. *E. guirandi* daha önce sadece Geç Kimmerisiyen'de Akdeniz Tetis'inde biliniyordu. Bu nedenle türün Güneybatı Japonya'da bulunuşu, türün bilinen biyocoğrafik ve stratigrafik yayılımını önemli ölçüde genişletmiştir. Ayrıca, *E. speciosum*'un Japonya'da Torinosu tipi kireçtaşlarında ve Sawarak'ta (Borneo) Bau kireçtaşı'nda bulunuşu da bu dönemde bu türün Tetis Alanı'nda yaygın olarak bulunduğunu gösterir. Doğu Tetis ve batı Pasifik'te ilk rudistlere ait bu bulgular, rudistlerin erken evrimsel tarihini anlamamıza yardımcı olmaktadır.

Anahtar Sözcükler: *Epidiceras*, rudist, Titoniyen–Berriasiyen, Torinosu tipi kireçtaşı, Torinosu Grubu, Güneybatı Japonya

Introduction

Almost all published records of rudists in the Diceratid Phase *sensu* Skelton (2003) come from the Mediterranean Tethys (Yanin 1989). However, scattered examples outside the Mediterranean Tethys, such as those from the Nova Scotia Shelf, Canada (Eliuk 1998), southwest Iran (Hudson & Chatton 1959; Wynn Jones 2006), northern Oman (Hudson & Chatton 1959; Skelton 2003), western Sarawak, Malaysia (Lau 1973; Skelton 1985) and Southwest Japan (Mimoto *et al.* 1990; Sano *et al.* 2007, 2008) indicate that rudists were already widespread throughout the Tethyan Realm and extended to the western Pacific Realm (geographic divisions based on Leinfelder *et al.* 2002) by the Late Kimmeridgian, a finding that has important implications for our understanding of the early history of rudists (Skelton 2003).

There are a few records of early rudists in the eastern Tethys and the western Pacific. Lau (1973) reported rudist species including *Heterodiceras* aff. *luci* (Defrance) from the Bau Limestone in Sarawak, Borneo, Malaysia, with the help of Dr. N.J. Morris of the British Museum (Natural History) for identification of rudists. However, Skelton (1985) mentioned the occurrences of *Epidiceras speciosum* (Goldfuss) and *Valletia* sp. from the Bau limestone, based on the observation of the specimens deposited in the Natural History Museum (London). Thus the record of *Heterodiceras* from Bau is not confirmed. On the other hand, Mimoto *et al.* (1990) gave the first report of the occurrence of a diceratid rudist from the Torinosu-type limestone in the Sakawa area, Shikoku Island, Southwest Japan. Recently, Sano *et al.* (2007, 2008) recognized three taxa of rudists, *E. speciosum*, *E. guirandi* (de Loriol) and *Monopleura* sp. in the Torinosu-type limestones in Kyushu and Shikoku Islands, Southwest Japan, though these rudists were identified mainly from sections of the shells, which are exposed on limestone surfaces. Since both of the Bau limestone and Torinosu-type limestones were originally deposited not on accreted seamounts but on the continental margin (e.g., Matsuoka 1992; Ting 1992), these records from the eastern Tethys and the western Pacific are important for considering the rudist palaeobiogeography at that time. However, these rudists have not been systematically described yet.

In this paper, two primitive rudists: *E. speciosum* and *E. guirandi* are described from the Tithonian–Berriasian Torinosu-type limestones from the Sakawa area, Shikoku, Southwest Japan, and the stratigraphical and palaeogeographical implications of their presence there are explored.

All specimens described in this paper are deposited in the Department of Earth Science, Faculty of Science, Kochi University (KSG).

Geologic Setting

Most of the *Epidiceras* specimens reported here were recovered from the abandoned limestone quarry in Ennogataki, Sakawa, Central Shikoku, Southwest Japan (Locality 1 in Figure 1). This quarry is the same as the Hitotsubuchi Quarry in Ohga & Iryu (2003) and Hitotsubuchi Eastern Quarry in Kano *et al.* (2006), but differs from the Hitotsubuchi Western Quarry mentioned in Kano *et al.* (2006) (= the quarry studied by Kano 1988). Other specimens were collected from the southwestern flank of the limestone body in Kooku, Sakawa, which marks the westernmost distribution of the Torinosu-type limestones in the Sakawa area (Locality 2 in Figure 1).

The Sakawa area is the type locality of the Late Jurassic to earliest Cretaceous age Torinosu Group, which was deposited in the fore-arc basin developed on the Jurassic accretionary complex, the Southern Chichibu Terrane (Matsuoka 1992). The Torinosu Group and its equivalents in central to western Shikoku were recently divided into two formations: the lower Tsukadani and the upper Yatsuji formations in the Sakawa area (Kano *et al.* 2006). The Tsukadani Formation is composed of mudstone, sandstone, and conglomerate occasionally containing small limestones blocks, and the Yatsuji Formation is mainly composed of mudstone and sandstone with lenticular fossiliferous limestone bodies (usually several hundreds metres in lateral extent and several tens of metres in thickness), called Torinosu-type limestones (Kano *et al.* 2006). Based on the occurrences of ammonoid and radiolarian fossils mainly from the siciliclastics, the Tsukadani Formation is assigned a Late Kimmeridgian–Early Tithonian age, and the Yatsuji Formation a Tithonian–Berriasian age (Matsuoka 1992; Kano *et al.* 2006). The rudist-bearing limestone bodies in Ennogataki and Kooku belong to the Yatsuji Formation.

Torinosu-type limestones contain an abundant carbonate platform biota, such as corals, stromatoporoids, benthic foraminifers, calcareous algae and calcified microbes, as well as ooids (e.g., Yokoyama 1890; Yabe & Hanzawa 1926; Yabe & Toyama 1928, 1949a, b; Yabe & Sugiyama 1935; Eguchi 1951; Endo 1961; Tamura 1961; Imaizumi 1965; Shiraishi & Kano 2004). They were interpreted as forming carbonate mounds in the shallow marine shelf (Kano 1988; Kano & Jiju 1995). Rudist specimens in Ennogataki were recovered around 1990 at the time of active quarrying (Mimoto *et al.*

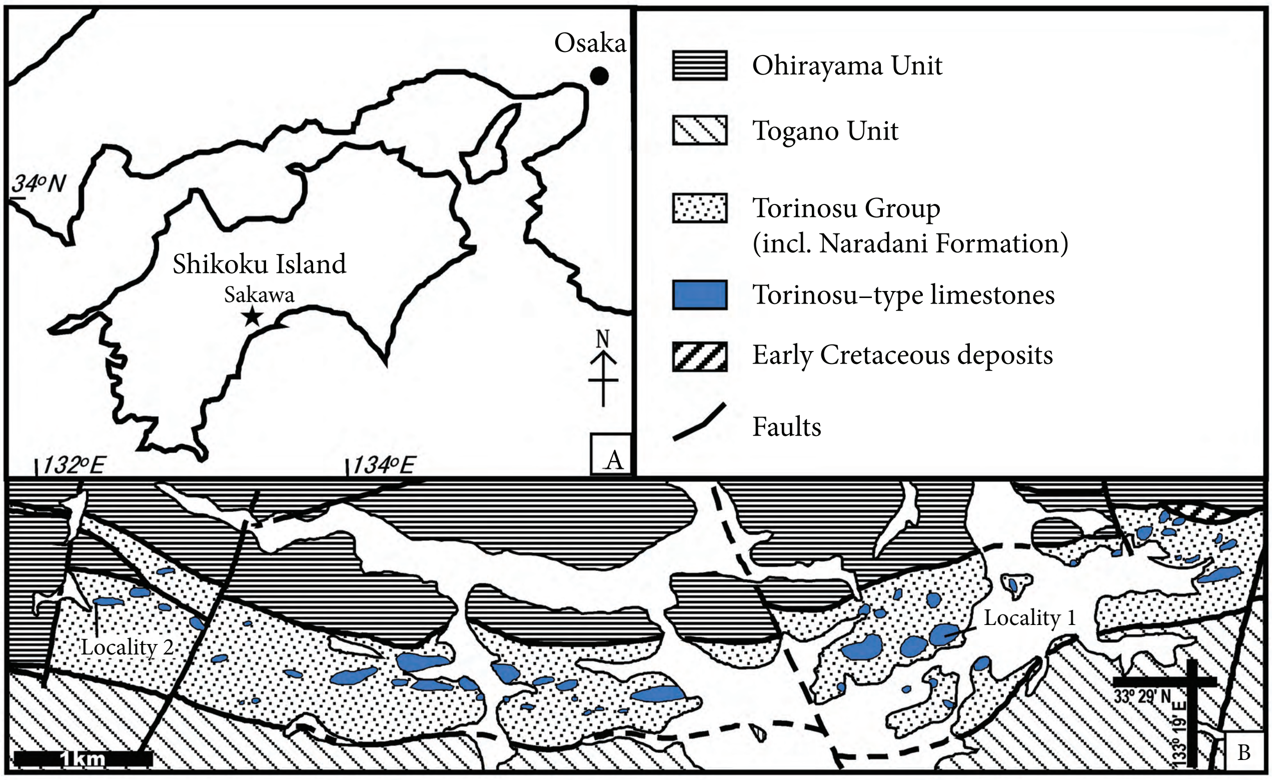

Figure 1. Localities of *Epidiceras* from the Torinosu-type limestones in the Sakawa area, Southwest Japan. Limestone bodies of the Torinosu-type limestones sporadically occur in the Torinosu Group, which is surrounded by, and is in fault contact with the Jurassic accretionary units: the Ohirayama and Togano units. Geologic map is modified from Katto (1982), though the names of accretionary complex units are based on Matsuoka *et al.* (1998).

1990). Collectors of the specimens informed us that specimens of *E. speciosum* occurred in the lowermost part of the limestone body, and specimens of *E. guirandi* in its middle part. Since most parts of the rudist-bearing horizon were lost during the quarrying operation or are now covered with thick soils, we cannot confirm the precise lithological and sedimentological context for the rudists, although Ohga & Iryu (2003) reported the occurrence of reefal biota in the remaining part of the Ennogataki limestone body. On the other hand, there is no geologic study of the limestone body in Kooku and its biota, though some coral and chaetetid specimens were recovered with rudists as scattered float in the southwestern flank of the limestone body.

The age of the Torinosu-type limestones in the Torinosu Group has been estimated as Late Jurassic mainly based on the ammonoid fossils from the siliciclastic units (e.g., Tamura 1961), but is still controversial, because at least some of the limestone bodies are interpreted as allochthonous blocks (e.g., Ishida *et al.* 2006; Kano *et al.* 2006). Thus the age of the Torinosu-type limestones should be discussed according to evidence obtained directly from the limestone bodies. In the recent review of all previously described ammonoids from the Torinosu Group, Sato (2007) mentioned two specimens from the limestone itself or adjacent locality to the limestone body in the Sakawa area. One is a juvenile specimen of *Haploceras*? sp., probably referable to the Kimmeridgian–Tithonian, from the limestone body near Naradani, which is located halfway between Ennogataki and Kooku, and the other, *Virgataxioceras*? *morimotoi* (Yehara), indicating the Middle Kimmeridgian, comes from the sandy mudstone near the limestone body of the Hitotsubuchi Western Quarry. However, the occurrence of ammonoids in the Torinosu Group is too sporadic to establish a reliable age-constraint

(Sato 2007). Furthermore, several ammonoids indicating different ages ranging from Kimmeridgian to latest Early Tithonian co-occur in the same horizon of the Kurisaka Formation, an equivalent to the Torinosu Group, in the Kurisaka area, eastern Shikoku (Sato *et al.* 2008). Thus the age assignment of the Torinosu-type limestones by ammonoids is not adopted at present.

Aita & Okada (1986) considered the age of the marl in the lowermost part of adjacent limestone body (= Hitotsubuchi Western Quarry), based on calcareous nannofossils, as latest Tithonian to earliest Berriasian. Uematsu (1996) studied the benthic foraminiferal assemblages from the limestone bodies in the Sakawa area, and suggested a Berriasian age. Kakizaki *et al.* (2008) demonstrated a Late Tithonian–Berriasian age for another limestone body near Naradani, based on the Sr isotope data of brachiopod shells. Furthermore, Shiraishi *et al.* (2005) suggested that most of the limestone bodies in the Torinosu Group should be assigned to the Tithonian–Berriasian. In summary, although no precise age information has been recovered directly from the Torinosu-type limestone bodies in Ennogataki and Kooku, we presume the age of the rudist-bearing limestone bodies to be Tithonian–Berriasian.

Systematic Palaeontology

Superfamily Hippuritoidea Gray 1848

'Family Diceratidae Dall' (Dechaseaux *et al.* 1969)

Remark

This family, as defined by Dechaseaux *et al.* (1969), comprises a paraphyletic grouping of phylogenetically basal rudists (Skelton & Smith 2000), united only by the retention of the following primitive character states: (1) an external parivincular ligament (hence spirogyrate valve growth); (2) a relatively thin (~1 mm) calcitic outer shell layer with fine external ribbing. It contains the basal members of two distinct clades of rudists, in which juvenile attachment to the substrate was by the right valve, and by the left valve, respectively (Skelton 2003).

Epidiceras Dechaseaux, 1952 [*ex* Douvillé 1935]

Type Species. Diceras sinistrum Deshayes

Remark

Douvillé (1935) restricted the genus *Diceras* to those species in which attachment was by the right valve (as in the type species, *D. arietinum* Lamarck), and proposed a new genus, *Epidiceras*, for species that were previously assigned to *Diceras*, but which attached by the left valve. However, he did not designate a type species and the new genus only became valid with the subsequent designation of *E. sinistrum* by Dechaseaux (1952), according to ICZN rules (Ride *et al.* 1999).

Skelton (1999, 2003) suggested that four genera of left valve-attached diceratids proposed by Pchelintsev (1959), *Eodiceras*, *Megadiceras, Mesodiceras,* and *Paradiceras,* could be considered as junior synonyms of *Epidiceras*, as the myophoral arrangements on which Pchelintsev's diagnoses were based in fact show considerable overlapping variation between the supposed 'genera'. In this paper, the genus *Epidiceras* is used according to the definition of Skelton (2003).

Epidiceras speciosum (Goldfuss)

Figure 2

1839 *Chama* (*Diceras*) *speciosum*, G. v. Münster, p. 107 [*nomen nudum*]

1840 *Chama speciosa* Münster, Goldfuss, p. 205, plate 139, figure 1c.

1999 *Epidiceras speciosum* (Münster), Skelton, p. 84, plate 2, figures 1–5, plate 3, figure 9.

2008 *Epidiceras speciosum* (Münster), Sano *et al.*, figures 7C–D & 8A.

Material

Three right valves: KSG-ss004 (collected by Mr. Kazuo NOSE from Ennogataki) and KSG-ss007 and ss009 (collected by Mr. Takayoshi HIROTA from Kooku). Two left valves: KSG-ss005 (collected by Mr. Yoshihiro MORINO) and KSG-ss006 (collected by Mr. Takao KAMOHARA) from Ennogataki.

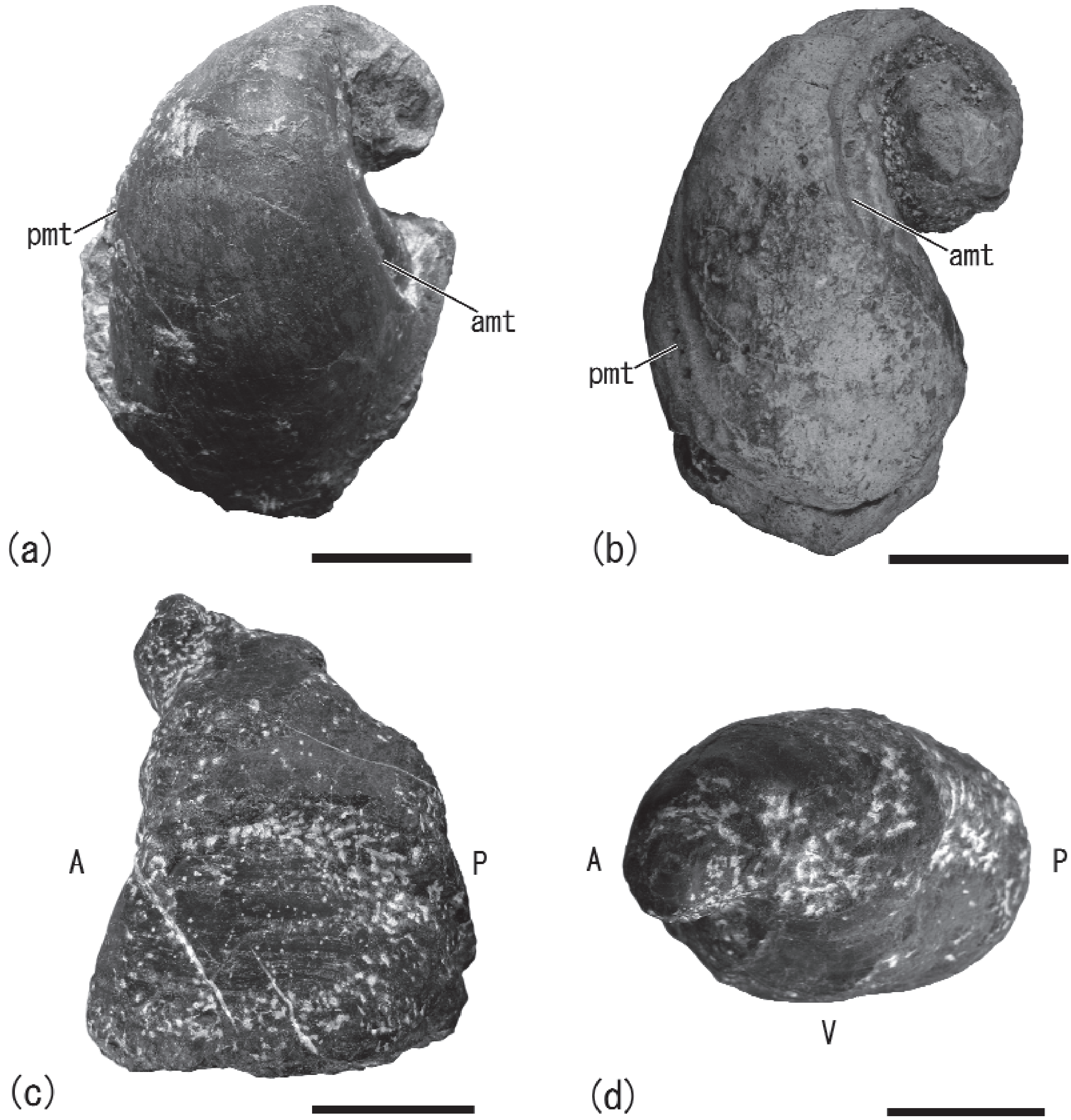

Figure 2. *Epidiceras speciosum* (Goldfuss) from the Tithonian–Berriasian Torinosu-type limestones in the Sakawa area, Central Shikoku, Southwest Japan. **(a)** Right valve exterior (KSG-ss004). Umbo is broken. Anterior and posterior myophoral traces (amt and pmt) are identified as longitudinal indentations on the anterior and posterior flanks of the shell. **(b)** Right valve exterior (KSG-ss007). Shell remains only in umbonal part and anterior flank of the shell. Coarsely-recrystallised belts passing longitudinally on the anterior and posterior flanks of the shell represent atm and ptm. **(c, d)** Left valve (KSG-ss006). A, P, and V represent anterior, posterior and ventral side of the shell, respectively. **(c)** Ventral, **(d)**, Umbonal View. Note secondary deformation: in the ventral view of the shell **(c)**, part of the flank of the valve is secondarily displaced lower, and the shell is probably compressed perpendicular to the commissural plane. Scale bar= 5 cm.

Description

Right Valves. The shells of 3 specimens are large, with an antero-posterior commissural diameter of almost 10 cm. The valves have a rounded commissural form, and both show relatively large expansion rates, with distinctly spirogyrally twisted umbones. The mode of expansion of the shells is variable, being stronger in KSG-ss007 and weaker in KSG-ss009. There is no indication of attachment by this valve, notwithstanding the loss of the umbonal tip in KSG-ss004.

In KSG-ss004 (Figure 2a), most of the thin (calcitic) outer shell layer has spalled off, leaving only a dark, recrystallised relic near the umbo, and otherwise exposing the smooth outer surface of the thick, originally aragonitic, but now recrystallised, inner shell. The inner shell has been partially excavated, moreover, to reveal the insertion traces of the adductor muscles, forming longitudinal indentations on the anterior and posterior flanks of the internal mould (amt and pmt in Figure 2a). In KSG-ss009, as in KSG-ss004, the outer surface of the recrystallised inner shell is exposed, though a dark relic of the outer shell layer is left near the umbo. Insertion traces of the adductor muscles have not been excavated in this specimen, but identified as longitudinal coarsely-recrystallised belts on the anterior and posterior flanks of the shell. In KSG-ss007 (Figure 2b), representing the internal mould, most of the shell wall is not preserved. The smooth outer surface of the inner shell layer is exposed on the anterior flank of the shell, and a dark relic of the outer shell layer is left in the posterior flank of the shell near the umbo. Coarsely-recrystallised belts (up to 1 cm in width) pass longitudinally on the anterior and posterior flanks of the shell to reveal the ridges of anterior and posterior adductor scars (amt and pmt in Figure 2b).

The anterior adductor trace shows that the muscle inserted directly onto the inner valve wall, where it evidently left an impressed scar demarcated ventrally by a narrow ridge running up into the umbonal cavity. The posterior adductor inserted onto a low myophoral ledge that passed immediately beneath the hinge plate, leaving a broad but shallow indentation and/or coarsely-recrystallised belt along the posterior flank of the internal mould. The dentition has not been observed in these specimens.

Left Valves. In KSG-ss006 (Figure 2c, d), the shell is large, with an antero-posterior commissural diameter of at least 13 cms and probably more, because of secondary deformation, such that precise measurements are difficult. The shape of the commissure is also indefinite. The umbo shows a spirogyrate twist, and a large expansion rate in the later stage of growth. A nearly flat area just posterior to the tip of the umbo possibly indicates deformed growth around the attached part of the shell. Fine longitudinal ribs occur on the thin outer shell layer mid-way along the ventral surface, together with a few concentric rugae in the later expanding part. Secondary deformation is also suggested: the shell is compressed perpendicular to the commissural plane such that the ventral face of the valve is fractured and displaced. The dentition and the myophoral structures are not visible.

In KSG-ss005, the shell is very large, with an antero-posterior commissural diameter of about 18 cm. Its shell is brownish grey in colour, in contrast to all the other specimens, which are black. It has a rounded commissural form and a large expansion rate. Though broken, its umbonal part has a spirogyrate twist. The thick inner shell, over 1cm thick in some parts, is exposed, with a smooth outer surface showing thin concentric growth lines. However, the thin outer shell layer is observed in places. The dentition and structures indicating myophoral parts are not recognized.

Remarks

The spirogyrate form of the valve, relatively thin outer shell layer and posterior adductor muscle insertion on a low myophoral ridge passing beneath the hinge plate are all consistent with assignment of the specimens to either of the two primitive diceratid genera, *Diceras* or *Epidiceras* (Skelton 1978, 1999). The large size of the specimen – unmatched by any known *Diceras* species – is typical of some described species of *Epidiceras*: *E. cotteaui* (Bayle) and *E. giganteum* Pchelintsev from the Oxfordian (Bayle 1873; Pchelintsev 1959), and Late Kimmeridgian to

Early Valanginian *E. speciosum* (Goldfuss) (Skelton 1999, 2003). Since only *E. speciosum* is time-equivalent to the Torinosu-type limestones in the Sakawa area, we tentatively assign the Sakawa specimens to *E. speciosum*, though relationships among those large species of *Epidiceras* remains for future research. The rounded commissure and the passage of the posterior adductor myophore so closely beneath the hinge plate in *E. speciosum* (Skelton 1999) are also concordant with those of the Sakawa specimens. The lack of evidence for attachment of the right valve, and presence of possible attachment in the left valve would again be consistent with the left valve-attached *Epidiceras*.

Stratigraphical Range and Geographic Distribution

The first appearance of *E. speciosum* is in the Upper Kimmeridgian of Kelheim, Germany and the French Jura, but it is also widely known from the Tithonian (Yanin 1989; Skelton 1999). '*Megadiceras*' Pchelintsev, which appears to represent a stratigraphically younger part of the same species lineage, may extend the range to the Early Valanginian (Skelton 2003), though the '*Megadiceras koinautense*' beds in Crimea have recently been referred to the uppermost Berriasian (e.g., Baraboshkin 2003). The age of the Sakawa specimens is concordant with these data.

Epidiceras speciosum also occurs in the Kimmeridgian–Tithonian Bau Limestone, Sarawak, Malaysia (Skelton 1985), the Late Kimmeridgian–early Tithonian limestone blocks in the Shirokawa area, Shikoku (Sano *et al.* 2007), a limestone block of possible Berriasian age in the Kohoku area, Shikoku, and the Late Jurassic limestone in the Youra area, Kyushu, Southwest Japan (Sano *et al.* 2008). Thus this species had a cosmopolitan Tethyan distribution extending to the western Pacific in the Late Kimmeridgian to Tithonian.

***Epidiceras guirandi* (de Loriol)**

Figure 3

1886–88 *Diceras Guirandi* de Loriol, de Loriol & Bourgeat, p. 266, plate 30, figures 1–5.

1990 Diceratid gen. et sp. indet., Mimoto *et al.*, p. 108, 110, figures 2, 3.

1999 *Epidiceras guirandi* (de Loriol), Skelton, p. 86, plate 3, figures 1, 2.

2008 *Epidiceras guirandi* (de Loriol), Sano *et al.*, figures 2D–I, 8B.

Material

4 bivalved specimens. KSG-ss001 and KSG-ss002 were collected by Mr. Kazuo NOSE from Ennogataki, and briefly described in Mimoto *et al.* (1990). KSG-ss003 from the same locality was provided by Mr. Kenji MIMOTO. KSG-ss008 was recovered by Mr. Takayoshi HIROTA from Kooku.

In KSG-ss001, the postero-ventral part of the specimen represents the internal mould of both valves, and only relics of the shell are left in the right valve. In KSG-ss002, the right valve and posterior part of the left valve are preserved as internal moulds. In KSG-ss003, the shell is preserved, but the postero-ventral part of both shells is broken, showing an antero-posterior section through the ventral part of both valves. In KSG-ss008, both valves are represented by an internal mould.

Description

The shells of all specimens are small, with an antero-posterior commissural diameter of almost 4 cm; subequivalve (left valve larger) with a relatively large expansion rate, forming a bulbous shape (Figure 3). The commissure is rounded to sub-hexagonal, with a blunt antero-ventral carina in the left valve (Figure 3f) and a bulge on the posterior side of the each valve (Figure 3d, e). The umbones are distinctly spirogyrally twisted, notwithstanding the loss of their tips (Figure 3b, f). Coarse longitudinal ribs (2–3 mm interval) on the surface of the thin outer shell layer extend to parts of the umbo in the left valve of KSG-ss001 (Figure 3c), though the outer shell layer is not preserved in other parts. The presence of coarse growth rugae is shown by rounded concentric ridges on the surface of the internal mould in the ventral part of the right valve of KSG-ss001 (Figure 3a) and also that of KSG-ss002 (Figure 3d).

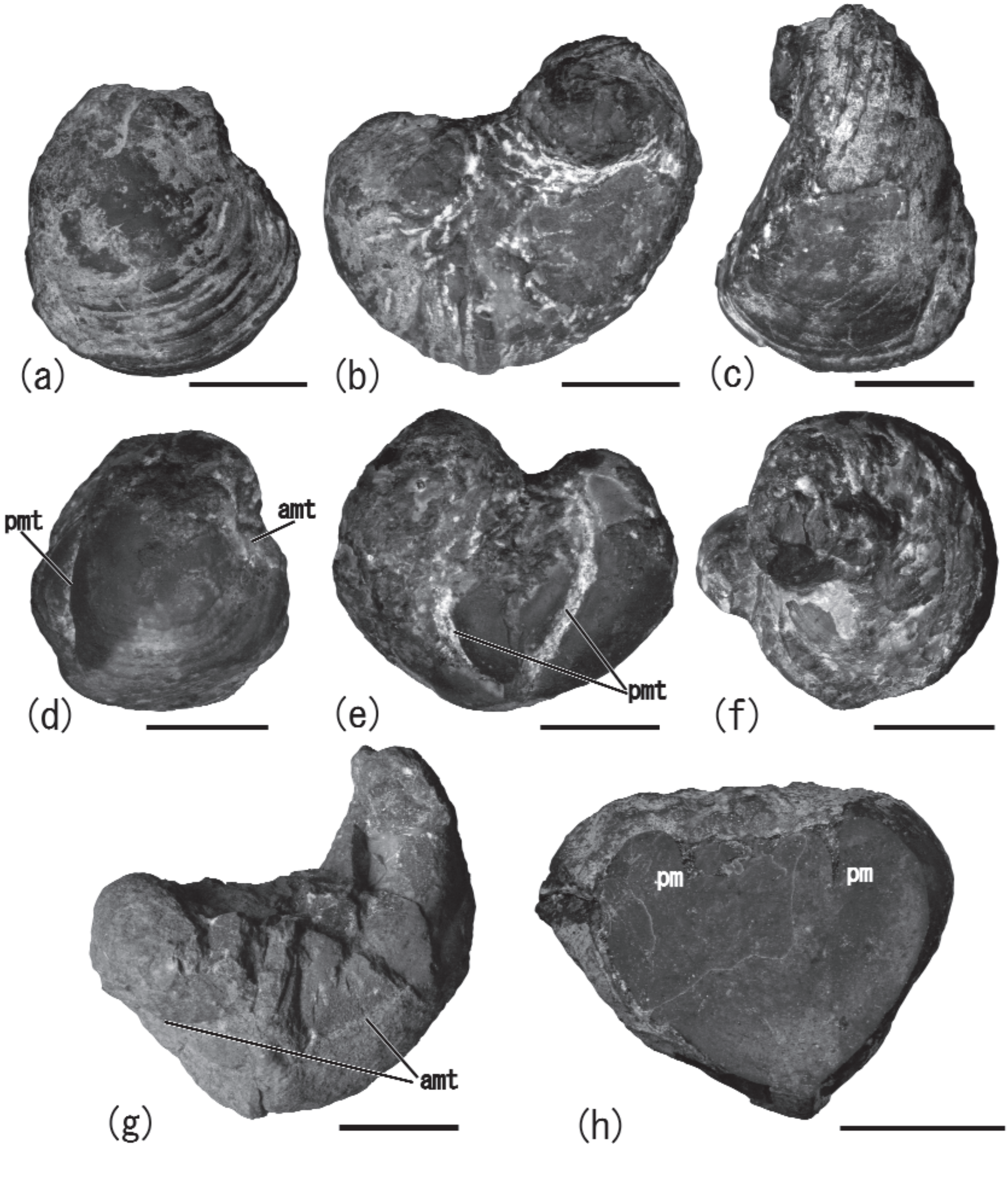

Figure 3. *Epidiceras guirandi* (de Loriol) from the Tithonian–Berriasian Torinosu-type limestones in the Sakawa area, Central Shikoku, Southwest Japan. **(a–c)** Bivalved specimen (KSG-ss001). **(a)** Right valve exterior. Coarse undulation occurs in the ventral part. **(b)** Anterior view. Umbones of both valves are broken. **(c)** Left valve exterior. Coarse longitudinal ribs occur in parts of the umbo. **(d–f)** Bivalved specimen (KSG-ss002). Note longitudinal indentations in the posterior flanks of both valves, and recrystallised calcite relics on the anterior flank of the right valve, indicating the anterior and posterior myophoral traces (amt and pmt). **(d)** Right valve exterior, **(e)** Posterior view, **(f)** Umbonal part of the left valve. Note a blunt antero-ventral carina. **(g)** Bivalved specimen (KSG-ss008). Anterior view. Longitudinal indentations on the anterior flanks of both valves represent anterior myophoral trace (amt). **(h)** Bivalved specimen (KSG-ss003). Antero–posterior section through ventral part of both valves. Note posterior myophoral ledges (pm) in each valve. Scale bar= 2 cm.

The posterior myophoral ledges (pm) in both valves are shown in antero-posterior section through the ventral part of KSG-ss003 (Figure 3h). Longitudinal indentations on the posterior flanks of the internal mould of the shell in KSG-ss002 and KSG-ss008 indicate the posterior myophoral traces (pmt), corresponding to the posterior myophoral ledges (Figure 3e). Insertion traces of the anterior adductor muscles have been identified as longitudinal indentations on the anterior flanks of both valves in KSG-ss008 (Figure 3g), or recrystallised calcite relics on the anterior flank of the right valve in KSG-ss002 (Figure 3d). Thus the anterior adductor inserted directly onto the inner valve wall, and the posterior adductor onto a low myophoral ledge that passed immediately beneath the hinge plate in each valve. The dentition was not observed in these specimens.

Remarks

The spirogyrate form of the valves, subequivalve condition (left valve larger), relatively thin outer shell layer, and posterior adductor muscle insertion on a low myophoral ridge passing beneath the hinge plate are all consistent with assignment of the specimens to *Epidiceras*. Several species of small *Epidiceras* have been proposed (e.g., Thurmann 1853; Bayle 1873; Karczewski 1969). But since their diagnostic differences of outer shell shape and also tooth form can be influenced by ecological factors (Skelton 1978), only two chronospecies, the Middle Oxfordian to Early Kimmeridgian *E. perversum* Sowerby and the Late Kimmeridgian *E. guirandi*, are tentatively considered valid (Skelton 1999 and personal observation). The two species show similar shape and myophoral arrangements, which are consistent with the Sakawa specimens, and differ only in size. The latter is larger, and corresponds to the Sakawa specimens.

Stratigraphical Range and Geographic Distribution

Epidiceras guirandi was previously known only from the Late Kimmeridgian of the French Jura (de Loriol & Bourgeat 1886–88; Skelton 1999). The Sakawa specimens from the Tithonian–Berriasian Torinosu-type limestones expand not only its geographic distribution but also its stratigraphic range more widely than previously thought. Possible occurrences of '*Eodiceras*' from Oman and Iran have been mentioned (Hudson & Chatton 1959; Wynn Jones 2006), and should be confirmed in future.

Conclusion

E. speciosum and *E. guirandi*, here described from the Tithonian–Berriasian Torinosu-type limestones from the Sakawa area, Shikoku, Southwest Japan are the first diceratids to be systematically described from the western Pacific. Since *E. guirandi* was previously known only from the Late Kimmeridgian in the Mediterranean Tethys, its occurrence in Southwest Japan extends both its biogeographical and stratigraphical distributions. *E. speciosum*, moreover, could be considered as the most widely-distributed rudist species at that time. Further studies of the rudists in the eastern Tethys and the western Pacific may contribute significantly to our understanding of the early evolutionary history of rudists.

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