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## Crinoid diversity in the Upper Cretaceous Yezo Supergroup, Hokkaido, northern Japan\*

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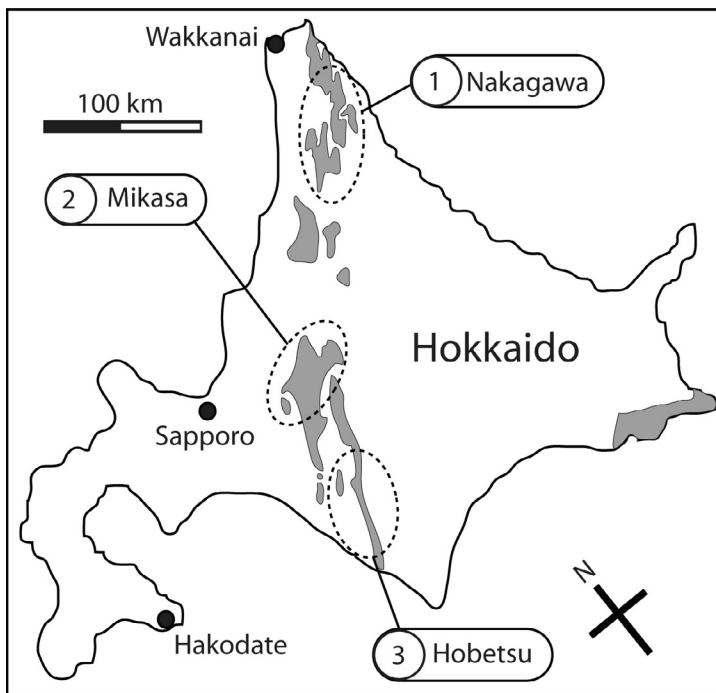
### Abstract

New data, principally from ‘local’ encrinites in the Yezo Supergroup of Hokkaido, northern Japan, suggest that many relict ‘Jurassic-type faunas’ identified in Europe and central Japan might have persisted in the Late Cretaceous deep-water (>100 m) muddy sandstone facies found throughout the island of Hokkaido. For example, *Isocrinus* and *Balanocrinus* occur in the outer shelf sandy mudstone facies of the Turonian-Coniacian Saku Formation and the Coniacian-Campanian Haborogawa Formation, of the Mikasa area (central Hokkaido), respectively. *Isocrinus* is also found in the Turonian-Coniacian deep-water siltstones and sandy siltstones of the Nishi-chirashinai Formation of the Nakagawa area (northern Hokkaido). In contrast, *Isselocrinus*, which belongs to ‘Late Cretaceous type-faunas’, occurs in the uppermost Cretaceous (Campanian) outer shelf mudstone facies of the Upper Yezo Supergroup around Hobetsu (south-central Hokkaido). Although collections of crinoids from the chalks of northern Europe are themselves largely free from sampling biases, Cretaceous crinoid diversity data have been markedly influenced by fossils preserved in the relatively homogeneous chalk facies where the faunal differences between the deep-water Danish, English and north German chalks (>250 m) and the shallow-water facies found around Maastricht, the Netherlands (<50 m) are slight. The results of this preliminary report on the crinoid faunas of Hokkaido suggest that global crinoid diversity reported from the Upper Cretaceous might be influenced by sampling and facies biases.

**Key words:** Crinoidea, Upper Cretaceous, Yezo Supergroup, Hokkaido, Japan, Mesozoic Marine Revolution

### Introduction

Studies into fossil crinoids have tried to understand why during the late Mesozoic to late Cenozoic stalked forms retreated into deep-water habitats (the shallowest modern population having been recorded at a depth of only 150–160 m), whilst leaving the comatulids to dominate the shallow shelves and reefs. The Marine Mesozoic Revolution is most often cited as the principal cause for this decline, and although the precise mechanism remains under investigation (Vermeij 1977), the lack of stalked forms in the early Cenozoic (post-Danian) is clear, with only relict populations found (Meyer & Oji 1993; Hess 1999, 2011). However, this cannot be said for the Jurassic and Cretaceous diversity; Baumiller *et al.* (2010) suggested that increased predation pressure by echinoids from the Middle-Late Triassic onwards might be an underlying cause of these diversity changes during the

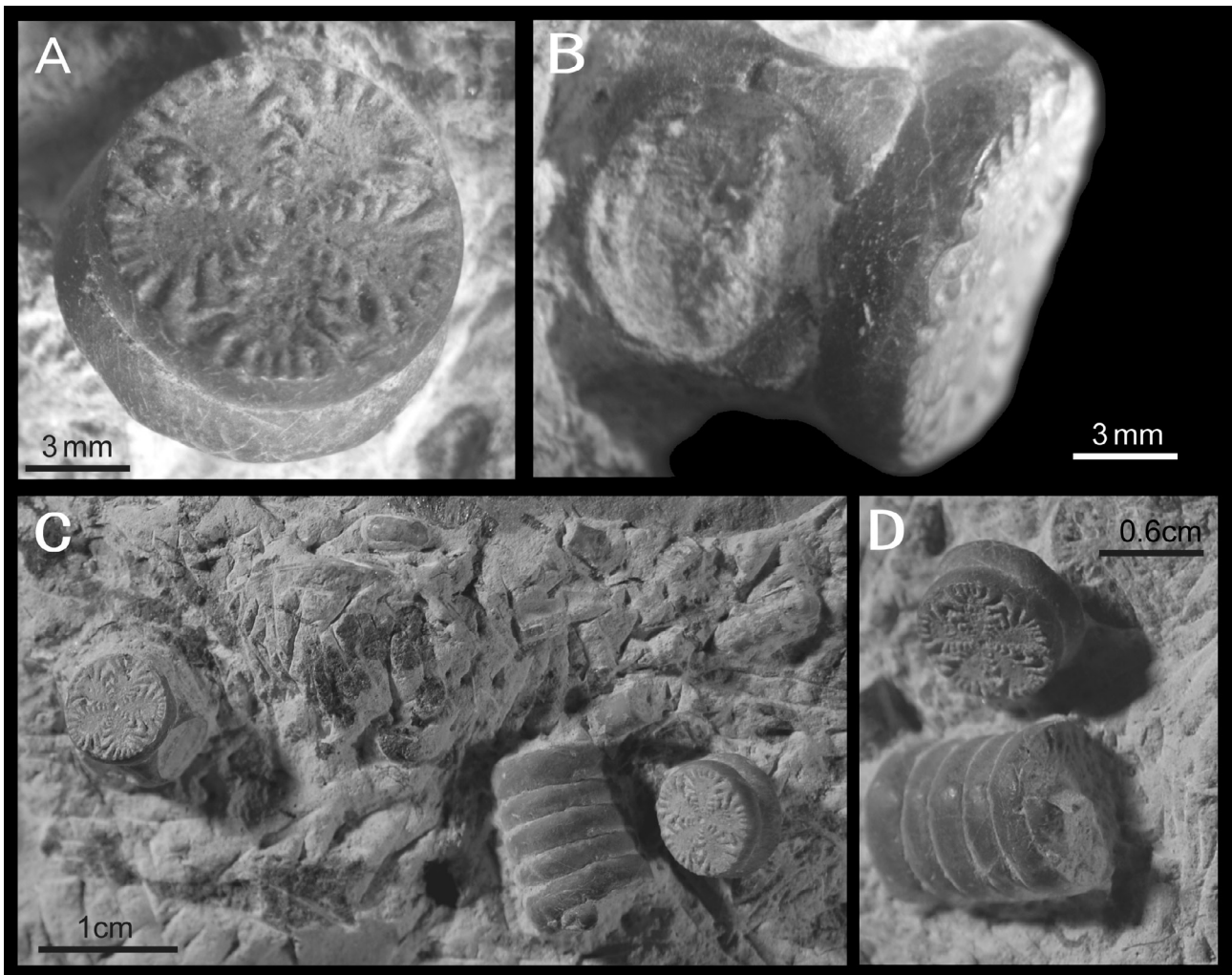


**FIGURE 1.** Map of Hokkaido showing the Cretaceous outcrops and the three principal areas from where the museum samples have been sourced.

Mesozoic. Throughout the early Mesozoic, both sessile and motile crinoids radiated to occupy a range of habitats, reaching an apparent morphological peak during the Early Jurassic (Simms 1988) and having a truly global distribution by the Middle Jurassic (Hunter & Zonneveld 2008; Hunter & Underwood 2009). Recently, it has been shown that the mainly motile ‘Jurassic-type faunas’ of *Isoocrinus*, *Balanocrinus* and *Chariocrinus* persisted well into the Early Cretaceous (Hunter *et al.* 2011), before declining and being replaced by ‘Late Cretaceous-type faunas’ such as *Isselocrinus*, *Nielsenocrinus* and *Austinocrinus* by the Aptian/Albian (Hess & Gale 2010). These ‘Late Cretaceous-type faunas’ are dominated by taxa adapted to living in the soft substrate chalk seas of northern Europe and North Africa and have been subject to extensive and rigorous taxonomic studies both for the relatively deep-water Danish and north German chalks (Rasmussen 1961; Schmid 1975), and their more shallow-water counterparts (Jagt *et al.* 1998; Jagt 1999). A similar treatment is also found in faunas from eastern Europe (see *e.g.*, Salamon 2009) and North and Central America; specifically Kansas (Milsom *et al.* 1994), Mississippi (Moore 1967), Texas (Peck 1943; Peck & Watkins 1972), Mexico (Rasmussen 1961) and Jamaica (Donovan *et al.* 1996). Relatively few surveys have been conducted elsewhere with Klikushin (1982, 1987) and Oji (1985) as notable exceptions. The present study aims to readdress this balance by surveying the existing but largely neglected crinoid fossils in museum collections from the Japanese island of Hokkaido. Although systematic collecting is at an early stage, I wish to show that even the most isolated and largely overlooked samples in museum collections can be significant in furthering our understanding of the evolution of Late Cretaceous crinoids.

### Study area

The three study areas (Fig. 1) fall into the catchment areas of three local museums that are largely responsible for prospecting for local fossil material; these are found across the length of Cretaceous outcrop in Hokkaido. From north to south they are the Nakagawa Museum of Natural History, the Mikasa Museum and the Hobetsu Museum. All material comes from the Yezo Supergroup, a com-



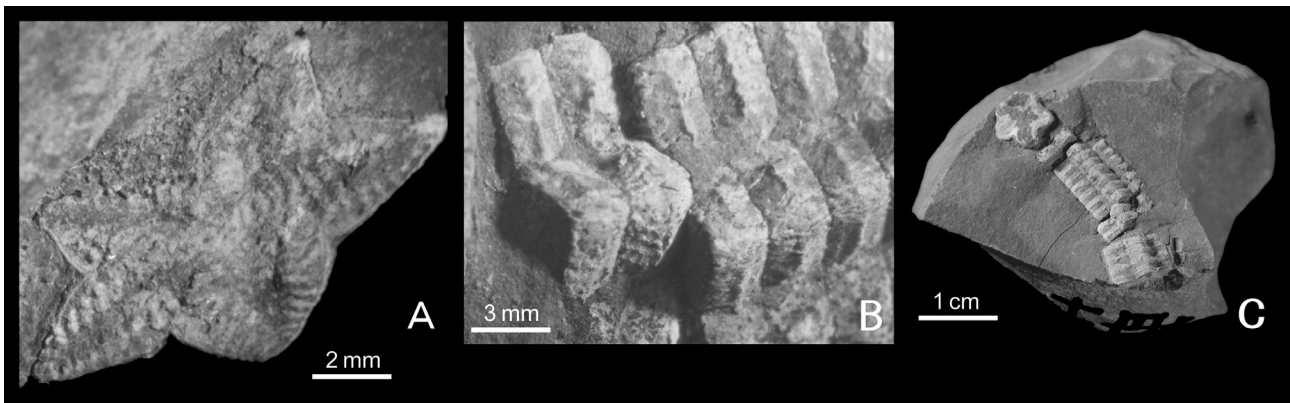
**FIGURE 2.** ?*Austinocrinus* sp., thought to be Santonian-Campanian (pers. comm. Dr. Ken'uchi Kurihara Mikasa Museum), locality unknown (UMUT ME31044).

plex series of formations that span the island. The geology of the entire Yezo is far too intricate to be reproduced here; however, good accounts were given by Kurihara *et al.* (2007) and Takahashi *et al.* (2007), to which reference is made.

Articulated crinoid material is rare and the 'local' encrinite beds and seldom collected, but comes from a wide range of lithologies and thus environmental settings. For each collection, all the material (almost entirely consisting of [pluri]columnals) was examined and identified. This has been supplemented by material, found in the collections of the University Museum (University of Tokyo; abbreviation: UMUT), that was of uncertain provenance before this survey was carried out. The taxonomic affinity and stratigraphic age of each columnal, along with the currently held interpretation of facies and depositional environment (DE), are summarized in Table 1, with the systematic description given for some given below. Many of these are being recorded for the first time from Japan.

### Systematic part

Classification follows that of Rasmussen (1961), Jagt (1999) and Hess (2011) Due to the poor preservation and lack of articulated material (cups or brachials), only generic designation is attempted at this stage.



**FIGURE 3.** *Isocrinus* sp., upper Turonian-Coniacian portion of the Haborogawa Formation, Kotanbetsu, Mikasa-shi, Hokkaido (UMUT ME31045).

### Genus *Austinocrinus* de Loriol, 1889

#### ? *Austinocrinus* sp.

Figures 2A-D

**Material.** One nodal and two pluricolumnals, associated on a bedding plane, so probably from a single individual, from an unknown locality, possibly in south-central Hokkaido (UMUT ME31044). thought to be Santonian-Campanian (pers. comm. Dr. Ken'uchi Kurihara Mikasa Museum).

**Description.** Columnals are rounded, stout and low, the articular face is smooth and narrow; the petals are lanceolate has five interrarial petals with slightly depressed areolae. The marginal crenellae have V-shaped, short crenellae radiating from a central lumen. Towards the edges, the crenellae are replaced by adradial ridges which are poorly developed on the specimens (Fig. 2A). The latera are rounded and unornamented (Fig. 2B). The number of cirri on each enlarged nodal is four, with closely packed rather large sockets which almost cover the entire nodal latera (Fig. 2B) and overlap the adjacent internodals.

**Discussion.** The crenulations are atypical of the genus, as the broad margin typical of *Austinocrinus* is largely absent. Although the articular face is isselicrinid or even praeisselicrinid like, with 5 elliptical petals and stout crenulae restricted to the marginal area with the pentalobate columnals strongly reduced towards the centre and adradial crenulae stout and clearly V-shaped (Fig. 2A), the specimen has been assigned to ?*Austinocrinus* based on the rounded and low columnal and slightly enlarged nodal and cirral scars that are very large and generally circular, covering the entire height of the nodal and most of the supranodal. Its is suggested that this specimen is part of the more proximal stem of an as yet undescribed morphotype of ?*Austinocrinus* which has convex rather than concave latera.

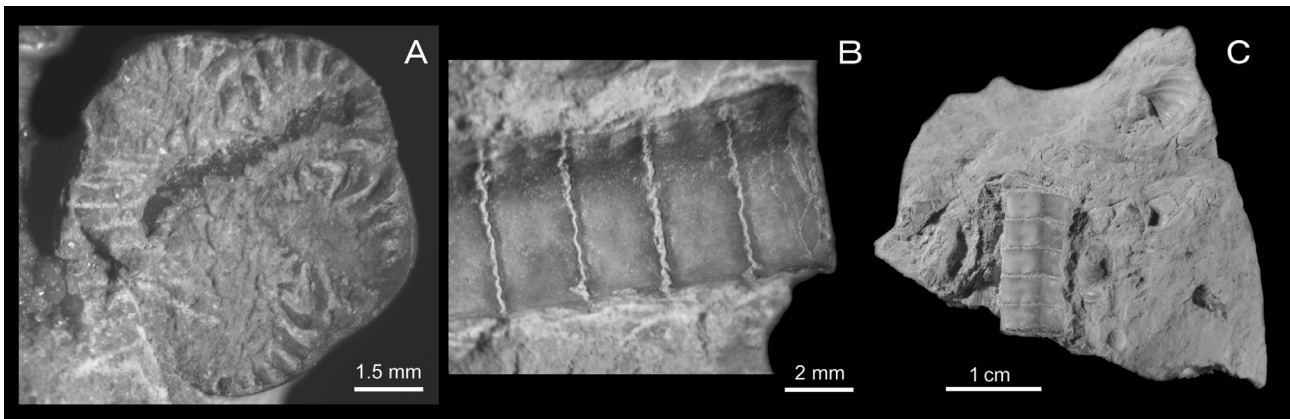
### Genus *Isocrinus* von Meyer in Agassiz, 1836

#### *Isocrinus* sp.

Figures 3A-C

**Material.** One pluricolumnal from the upper Turonian-Coniacian portion of the Haborogawa Formation, Kotanbetsu, Mikasa area (UMUT ME31045) three pluricolumnals and >20 columnals from the upper Turonian-Coniacian Saku Formation, Mikasa Town; section 15 of internodals (nodals morphol-





**FIGURE 4.** ?*Balanocrinus* sp., upper Coniacian-Campanian portion of the Haborogawa Formation, Obira-Kotanbetsu, Mikasa-shi, Hokkaido (UMUT ME31046).

ogy) and one pluricolumnal from the Turonian-Coniacian Nishichirashinai Formation at Abeshinai River and Itaya, Tenmi-zawa, of the Nakagawa area (Table 1).

**Description.** Columnals are subrounded, pentalobate to pentagonal; only columnals are preserved, with most taxonomic information found in the articular face. Internodals are subpentagonal to pentalobate (Fig. 3A), sometimes subrounded. Internodal articulations are symplectial. The facets of columnals have elliptical petals, with gradual continuation of marginal and adradial crenulae reaching greatest length in radial marginal areas (Fig. 3A). Adradial crenulae of adjacent areolae are generally separated and at a slight angle to each other except near the lumen (Fig. 3A).

**Discussion.** Several species have been attributed to *Isocrinus*. Rasmussen (1961) used the name “*Isocrinus*” to refer to those crinoids that were unidentifiable and that were more likely to belong to *Nielsenicrinus* or later early Palaeocene genera. This is due to Rasmussen (1961) defining *Nielsenicrinus* on characters in the arms (syzygial articulation Br1–2). However, I find no evidence that these examples warrant any assignment to *Nielsenicrinus*, either on characters of the articular face, where the adradial crenulae are weakly developed near the lumen, or in the occurrence of granules on the entire surface of the latera. At this stage further systematics has not been attempted; however, it is very likely that at least two species are represented within the Upper Cretaceous of Hokkaido. For example, morphotype 1 has a line of granules on the median ridge of the latera and flat low columnals (Fig. 3B), while morphotype 2 has rounded, taller columnals. Only when more material becomes available will further formal designation be attempted.

### Genus *Balanocrinus* Agassiz in Desor, 1845

#### ?*Balanocrinus* sp.

Figures 4A–C

**Material.** One pluricolumnal from the upper Coniacian-Campanian portion of the Haborogawa Formation, Obira and Kotanbetsu (UMUT ME31046)

**Description.** Sub-rounded columnals are rather tall. Symplectial areolae on the articular face are broadly elliptical and the adradial crenulae are fused into a single ridge (Fig. 4A). Marginal crenulae, of which there are 9–10 relatively large ones (Fig. 4A), are partly fused, forming a V-shaped structure at the junction of two petals (Fig. 4A). The latera are smooth and unornamented (Fig. 4B).



**FIGURE 5.** *Isselicrinus* sp., Campanian, Upper Yezo Super-group, Hobetsu Town, Yūfutsu-gun, Hokkaido (HM 1098).

**Discussion.** My assignment to *Balanocrinus*, albeit with a query, is based on the distinctive arrangement of the crenulae which have V-shaped marginal crenulae and weakly developed adradial crenulae that form a faint ridge. However, this ridge is too poorly developed to resemble the one in *Isselicrinus*. In addition, this specimen could not belong to the genus *Nielsenicrinus* as columnal latera are smooth, not granular, and the columnal is far too rounded.

#### **Genus *Isselicrinus* Rovereto, 1914**

##### ***Isselicrinus* sp.**

Figure 5

**Material.** One pluricolumnal and five very poorly preserved columnals, Campanian, Upper Yezo Group near Hobetsu Town, Yūfutsu-gun, Hokkaido (HM 1098).

**Description.** Columnals are pentalobate to cylindrical. The articular faces of the columnals only have >14 crenellae around the outside (marginal crenulae) with the adradial crenellae being fused as a double (ad)radial ridge with a gradual transition between the two (Fig. 5). Areolae are broad and teardrop shaped. Latera are smooth and cirral sockets, are not visible.

**Discussion.** Although representing the most poorly preserved material in this study, it is still possible to recognize the diagnostic radial ridges and marginal crenellae on the articular face of the columnal. The radial ridge is too well developed to resemble *Balanocrinus*. In addition *Isselicrinus* lacks crenulae in the central part of the articular face. Furthermore, the columnal is far too rounded to be placed either in *Isocrinus* or *Nielsenicrinus*.

#### **Discussion**

Although samples are limited at this stage, these new data suggest that relict ‘Jurassic-type faunas’ persisted in the Late Cretaceous Yezo Supergroup of Hokkaido. This indicates the occurrence of *Isocrinus* and ?*Balanocrinus* in the outer shelf sandy mudstone facies of both the upper Turonian-Coniacian Saku Formation and the upper Coniacian-Campanian portion of the Haborogawa Formation

of Mikasa, central Hokkaido. *Isocrinus* is also found in the deep-water siltstones and sandy siltstones of the Nishi-chirashinai Formation in the Nakagawa area, northern Hokkaido. Although species of *Isocrinus* were noted both by Rasmussen (1961) and Jagt (1999) in the Campanian/Maastrichtian (and lower Danian) of Europe and North Africa, their diagnoses were uncertain and thus more work needs to be done to define the actual range of this genus. The genus *Balanocrinus* has never been recorded higher than the mid-Cretaceous (Albian) (Hess & Gale 2010). Although Hess (2011: 58), notes “?Cenomanian, ?Santonian”, but no citation is given for these dates), thus if the occurrence of this genus is confirmed in Hokkaido by new material, this genus would range from the Sinemurian to the Campanian. In contrast, *Isselocrinus* and *Austinocrinus* (the latter from an unknown locality) which belong to more ‘Late Cretaceous-type faunas’ are found in the uppermost Cretaceous (Campanian) outer shelf mudstone facies of the Upper Yezo Supergroup around Hobetsu (south-central Hokkaido), in localities better known for their marine reptile remains. The discovery of *Isselocrinus* in the Campanian could be the oldest occurrence of this genus, with all other examples found from the lower Maastrichtian onwards.

It is clear that the sediments in Hokkaido represent a distinct facies deposited at >100 m depth, broadly consisting of muddy, fine-grained sandstones. Until now this was overlooked, with the majority of monographic works on Cretaceous crinoids being based on the Chalk facies of Europe, North Africa and North America. Although the collections of crinoids preserved in the chalks of northern Europe are themselves largely free from sampling biases (Hunter & Donovan 2005), Cretaceous crinoid diversity data have been heavily influenced by fossils preserved in the relatively homogeneous chalk facies where the faunal difference between the deep-water Danish, English and north German chalks (>250 m) and the shallow-water facies found around Maastricht, the Netherlands (<50 m) are slight (Hunter & Donovan 2005). The results from Hokkaido, although strictly a preliminary study with more crinoid samples needed, suggest that the diversity, generic ranges and facies association of key crinoid genera need to be re-examined. Even with these relatively poorly preserved examples, the results are highly significant.

**TABLE 1.** Origin of the crinoid ‘local encrinites’ samples from Hokkaido. EOD = Environment of Deposition. \*Santonian-Campanian (pers. comm. Dr. Ken’uchi Kurihara Mikasa Museum).

Age	Lithostratigraphy	Facies/EOD	Town/Area	District or City	Taxa
Campanian	Upper Yezo Group	Outer shelf mudstone	3 = Hobetsu Town	Yūfutsu-gun	<i>Isselocrinus</i> sp.
*Santonian-Campanian	Unknown	Unknown	Unknown	Unknown	? <i>Austinocrinus</i> sp.
Upper Coniacian-Campanian	Haborogawa Fm.	Outer shelf sandy mudstone	2 = Obira Kotanbetsu	Mikasa-shi	? <i>Balanocrinus</i> sp.
Upper Turonian-Coniacian	Haborogawa Fm.	Outer shelf sandy mudstone	2 = Kotanbetsu	Mikasa-shi	<i>Isocrinus</i> sp.
Upper Turonian-Coniacian	Saku Fm.	Outer shelf sandy mudstone	2 = Mikasa Town	Mikasa-shi	<i>Isocrinus</i> sp.
Coniacian	Nishi-chirashinai Fm.	Deepwater siltstones and sandy siltstones	1 = Abeshinai River	Nakagawa-gun	<i>Isocrinus</i> sp.
Turonian	Nishi-chirashinai Fm.	Deepwater siltstones and sandy siltstones	1 = Itaya, Tenmizawa	Nakagawa-gun	<i>Isocrinus</i> sp.

## Conclusions

I believe that this small sample of crinoid columnals has not only started to fill an important gap in the Japanese Cretaceous fossil record, but has implications for an incomplete global fossil record of this group. It is clear that many of these genera need to be re-examined in order to establish their definitive stratigraphic range or to establish if their occurrence is influenced by the sampled facies biases. It is essential that the true biodiversity of Late Cretaceous crinoids be resolved before we can make any further interpretations about biodiversity changes during the Mesozoic Marine Revolution.

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