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A new late Eocene *Bicornucythere* species (Ostracoda, Crustacea) from Myanmar, and its significance for the evolutionary history of the genus

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Abstract

The ostracode genus *Bicornucythere* (Ostracoda, Crustacea) is abundant in modern-day eutrophic marine bays, and is widely distributed in estuaries and inner bays throughout East Asia, including in China, Korea, Japan, and the Russian Far East. The evolutionary history of *Bicornucythere* is poorly understood. Here, we report on a new species of *Bicornucythere* (*Bicornucythere concentrica* **sp. nov.**) from the upper Eocene Yaw Formation in the Central Myanmar Basin. The oldest previously known *Bicornucythere* taxon, *Bicornucythere secedens*, was reported from lower Miocene strata in India, although a molecular phylogeny suggests that the genus first appeared in the Late Cretaceous. *Bicornucythere concentrica* **sp. nov.** is at least 10.9 million years older than the earliest known *B. secedens*. The new species occurs with *Ammonia subgranulosa*, a benthic foraminifer, an association that is representative of brackish water conditions in modern Asian bays. Our findings indicate that extant genera have inhabited Asian bays since the late Eocene. The paleobiogeography of *Bicornucythere* indicates that the taxon was dispersed onto Indian coasts during the collision between the Indian and Eurasian plates.

Key words: Asia, fossil, Yaw Formation, Central Myanmar Basin, paleobiogeography

Introduction

Bicornucythere bisanensis (Okubo, 1975) (Ostracoda, Crustacea) is widespread in the inner bays of East Asia, and is currently distributed along the coasts of China, Korea, Japan, and the Russian Far East at latitudes of 22°N to 43°N (e.g., Zhao & Wang 1988; Zenina & Schornikov 2008; Irizuki & Seto 2004; Irizuki *et al*. 2009). The species exhibits a high tolerance for variable conditions (Ikeya & Shiozaki,1993), and generally dwells in mud substrates with salinities higher than 20 psu; it can also survive in dysoxic conditions (dissolved oxygen concentrations of ~0.7 ml/l; Irizuki *et al*. 2003). At the heads of bays and in the central basins of enclosed inner bays, *B. bisanensis* may account for over 90% of the ostracode assemblage (e.g., Ikeya & Shiozaki 1993). The abundance of the species in Japanese bays has been increasing since the 1960s, following intensified eutrophication related to accelerated industrialization and urbanization (Yasuhara *et al*. 2003, 2007). *Bicornucythere bisanensis* is commonly associated with *Ammonia beccarii,* a benthic foraminifer (e.g., Yasuhara and Yamazaki 2005).

In Japan, the oldest record of *B. bisanensis* (*B.* cf. *bisanensis*; Iwatani & Irizuki 2008; Iwatani *et al*. 2009) is from late Pliocene strata (3.7–2.8 Ma), and the species appears to have invaded the Japanese Islands at this time (Ishizaki 1990). However, the evolutionary history of *Bicornucythere* has not yet been discussed. Fossil records of the genus are sporadic, and the oldest previously known *Bicornucythere* species, *B. secedens*, is from lower

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the Indian plate has moved northeastward, collided with the Eurasian plate, and deformed southeastern Asia (e.g., Ali & Aitchison 2008; Van Hinsbergen *et al*. 2012). During the collision, the Tethyan Seaway shallowed and vanished. During the late Eocene, the Indian plate was already sutured to the Eurasian plate (Morley 2009; Hall 2012). We suggest that *Bicornucythere* dispersed from southeast Asian coasts onto Indian coasts during the collision. Dispersion was possibly facilitated by the presence of contiguous coastlines between the Indian and Eurasian continents. Previous biogeography studies have principally addressed terrestrial biotic exchanges between India and Asia during the collision event (e.g., Hausdorf 2000; Briggs 2003; Li *et al*. 2013). Our finding suggests a marine biogeographic connection between the Indian and Eurasian coasts that were affected by the continental collision.

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APPENDIX. Measurements of *B. bisanensis* and *B. concentrica* **sp. nov.**

The specimens of *Bicornucythere bisanensis* were collected from two exposures (Locations 2 and 7) of muddy fine-grained sandstone of the Pleistocene Omma Formation, in Kanazawa Prefecture, central Japan. The Omma Formation consists of thin tuff layers and muddy fine-grained sandstone bearing fossil molluscs and ostracodes (e.g., Ozawa & Kamiya 2001; Kitamura & Kimoto 2006). Location 2 (36.52947°N, 136.68397°W) is 0.6 m above the base of the O3 tuff layer, while Location 7 (36.52912°N, 136.68383°W) is 8.8 m below the base of the O3 tuff layer.

Previous studies have reported variable morphotypes of *B. bisanensis* (e.g., Abe 1988; Irizuki & Seto 2004; Ozawa 2009). *Bicornucythere bisanensis* in this study is identified as Form A of Abe (1988). In the Omma specimens, the mean L and mean H of adult male left valves are 816 µm and 418 µm, respectively. The mean values fall within the ranges of L and H in the Form A morphotype (780–840 µm and 390–420 µm, respectively), as indicated by Abe (1983) from measurements of specimens from Aburatsubo Bay, Japan.

In the permutation test, we examined the null hypothesis that there is no difference between the WM/L ratios of adult (A) and juvenile (A-1 and A-2) instars; the null hypothesis was rejected at a significance level of less than 0.01 (p-value = 2.0×10^{-3}). Abbreviations: L = length, H = height, WM = width of marginal infold, LV = left valve, RV = right valve.

Taxon	Instar	Type of valve	L (µm)	H (µm)	WM (µm)	WM/L ($\times 10^{-2}$)	Locality	Remark
B. bisanensis	A	LV	788	429	81	10	2	Female
B. bisanensis	A	LV	832	458	88	11	2	Female
B. bisanensis	A	LV	779	431	78	10	2	Female
B. bisanensis	A	LV	782	440	86	11	2	Female
B. bisanensis	A	LV	842	447	93	11	2	Female, Fig. 5A, B
B. bisanensis	A	LV	816	398	83	10	2	Male
B. bisanensis	A	LV	790	407	61	7.7	2	Male
B. bisanensis	A	LV	804	414	55	6.8	2	Male
B. bisanensis	A	LV	821	424	67	8.2	2	Male
B. bisanensis	A	LV	780	437	79	10	7	Female
B. bisanensis	A	LV	792	452	94	12	7	Female
B. bisanensis	A	LV	764	437	86	11	7	Female
B. bisanensis	A	LV	774	443	86	11	7	Female
B. bisanensis	A	LV	805	375	88	11	7	Male
B. bisanensis	A	RV	784	421	64	8.2	2	Female
B. bisanensis	A	RV	767	415	81	11	2	Female
B. bisanensis	A	RV	750	406	92	12	2	Female
B. bisanensis	A	RV	788	427	54	6.9	2	Female
B. bisanensis	A	RV	806	437	76	9.4	2	Female
B. bisanensis	A	RV	759	413	55	7.2	2	Female
B. bisanensis	A	RV	781	434	90	12	2	Female
B. bisanensis	A	RV	759	422	84	11	2	Female
B. bisanensis	A	RV	737	411	83	11	2	Female

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