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An Early Albian Arctic-type ammonite *Arcthoplites* from Hokkaido, northern Japan, and its paleobiogeographic and paleoclimatological implications

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ABSTRACT

An Early Albian Arctic-type ammonite *Arcthoplites* was discovered from the Kamiji Formation of the Yezo Group in the Nakagawa area, northern Hokkaido, northern Japan. This is the first reliable record of a hoplitid ammonite from Japan and clearly indicates the distribution of an Arctic fauna in the middle latitudes of the North Pacific at that time. Synchronously with the appearance of this Arctic-type ammonite, the tropical Tethyan biota (Mesogean taxa) disappeared from Hokkaido and elsewhere in the Northwest Pacific. These biogeographic changes suggest the existence of a “cooling” episode in the Early Albian North Pacific.

1. Introduction

The Cretaceous period was generally characterized by warm climate. Mid-Cretaceous (Aptian–Turonian) in particular was a well-documented greenhouse period of global importance during the Earth’s history and associated with higher atmospheric CO_2 levels (Bice and Norris, 2002). Marine long-term oxygen isotope records suggest that a significant global warming trend during mid-Cretaceous and its optimum occurred largely in the Turonian (e.g., Jenkyns et al., 1994; Clarke and Jenkyns, 1999; Huber et al., 2002; Wilson et al., 2002; Steuber et al., 2005). On the other hand, evidence for cooler episodes exists, particularly in the Early Cretaceous (e.g., Kemper, 1987; Price, 1999; Price et al., 2000).

Abundant ammonite shells preserved in Cretaceous marine deposits are particularly useful for reconstruction of the paleobiogeography and marine paleoenvironments of this period (e.g., Cecca, 1998; Bengtson and Kakabadze, 1999). Some Albian ammonite genera (e.g., *Leymeriella*, *Brancoceras*, *Arcthoplites*, *Hoplites*, and *Mortoniceras*) have also been utilized for paleogeographic, paleobiogeographic and paleoclimatological purposes, although mainly in Europe (e.g., Owen, 1973, 1996; Baraboshkin, 1996). The distribution of *Arcthoplites*, a typical Arctic ammonite, was restricted to the Early Albian Arctic–Boreal regions (Imlay, 1961; Jones and Grantz, 1967; Birkelund and Håkansson, 1983; Wright et al., 1996; Baraboshkin, 1992, 1996; Casey, 1999; Baraboshkin and Mikhailova, 2005), and this genus is regarded as a good indicator for cool climatic conditions. *Arcthoplites* has been subdivided into two phylogenetically related subgenera *Arcthoplites* s.s. and *Subarcthoplites* (Baraboshkin, 1992; Baraboshkin and Mikhailova, 2005). Both subgenera are known to occur from the Lower Albian (*Leymeriella tardefurcata* Zone), and in general, *Subarcthoplites* occurs in slightly younger strata than *Arcthoplites* s.s. (e.g., Baraboshkin, 1996, 2004). In this paper I report a new specimen of *Arcthoplites* from the Yezo Group of northern Hokkaido (Fig. 1), that represents the first reliable hoplitid ammonite from Japan located at middle latitudes of the Cretaceous Northwest Pacific. This finding indicates the existence of a “cooling” episode in the Albian North Pacific.

2. Geological settings

The Yezo Group is represented by a thick clastic sedimentary sequence, about 8000 m in total thickness, deposited in the Aptian–Paleocene fore-arc basin of the East Asian active margin that extended from southern Hokkaido to Sakhalin Island (Far East Russia) (e.g., Okada, 1983; Takashima et al., 2004). The Upper Cretaceous part of the Yezo Group contains abundant macro- and microfossils at various horizons (e.g., Matsumoto, 1942, 1943; Toshimitsu et al., 1995; Takashima et al., 2004; Shigeta and Maeda, 2005) and is a reference marine Cretaceous succession in the circum-North Pacific regions. In contrast to the Upper Cretaceous part, the Lower Cretaceous part of the Yezo Group is extremely scarce in macrofossils.

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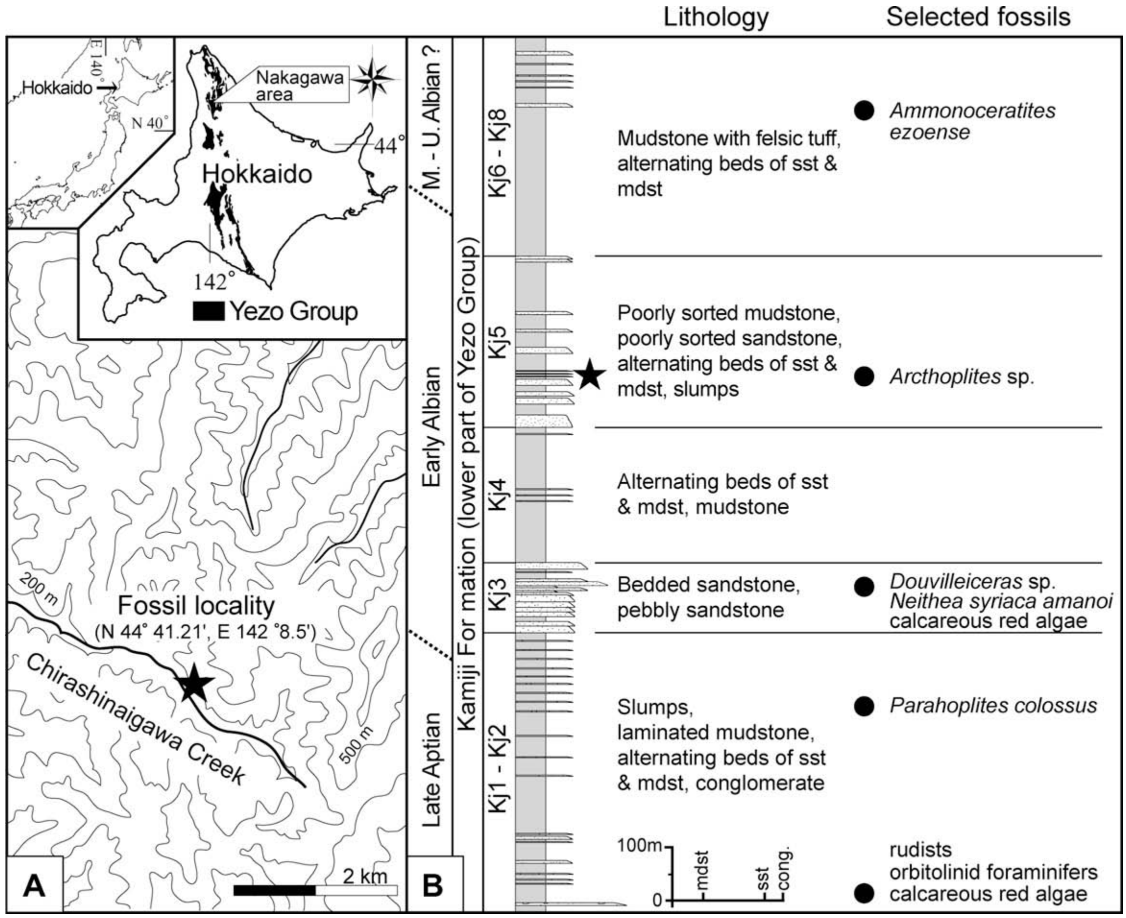

Fig. 1. Locality (A) and horizon (B) of the *Arcthoplites* specimen examined (indicated by stars). The columnar section is mainly based on fieldwork and observations of the exposure along the Chirashinaigawa Creek.

The Yezo Group in the Nakagawa area, northern Hokkaido is subdivided into nine formations; the Kamiji, Mehoro, Shirataki, Sakotandake, Sakugawa, Saku, Nishichirashinai, Omagari, Osoushinai formations in ascending order (Kawaguchi, 1997; Takahashi et al., 2003). The Kamiji Formation stratigraphically represents the lowest of the Yezo Group in this area. The formation consists mainly of mudstone and alternating beds of sandstone and mudstone, and is subdivided into eight members (Kj1 to Kj8 in ascending order) by Hashimoto et al. (1967) (Fig. 1). Representative fossils of Tethyan biota (e.g., rudists, *Orbitolina* (*Mesorbitolina*) *parva* and calcareous red algae) are abundant in the limestone clasts of the conglomeratic beds of the Kj1 Member. They indicate Late Aptian age (Iba and Sano, 2006, 2007). A Late Aptian ammonite *Parahoplites colossus* was reported from the Kj2 Member (Matsumoto, 1984). Iba and Sano (2007) reported an Early Albian ammonite, *Douvilleiceras* sp., calcareous red algae, and *Neithea syriaca amanoi* (a Tethyan non-rudist bivalve *sensu* Dhondt, 1992) from the Kj3 Member. In addition, an Albian ammonite *Ammonoceratites ezoense* was recorded from the Kj7 Member (Hayakawa, 1999). This species is common in the Lower–Middle Albian of the Yezo Group (Hayakawa, 1999). The horizons of these selected fossils are shown in Fig. 1B.

3. Occurrence of *Arcthoplites* from the Kamiji Formation in northern Hokkaido

A single specimen of the hoplitid ammonite *Arcthoplites* was recovered from mudstone of the Kj5 Member of the Kamiji Formation in the Nakagawa area, northern Hokkaido, at the exposure along the Chirashinaigawa Creek (Figs. 1 and 2), together with an assemblage consisting of other ammonites (i.e., *Brewericeras*?, *Tetragonites*, and *Cleoniceras*?), a belemnitid *Neohibolites*, and inoceramid bivalves. The Kj5 Member is more than 200 m thick in this section and consists of poorly sorted massive mudstone and alternating beds of sandstone and mudstone. Sandstone beds represent fine-grained turbidite facies. In this member, ammonites are very rare and embedded with their lateral sides parallel to the bedding plane. Upper flanks of ammonites are often dissolved away and/or deformed during diagenesis, but no fragmentation of shells was observed. These observations indicate that ammonite shells were not transported over a long-distance after death of animals.

Previous works have shown that *Arcthoplites* is restricted in occurrence to the Lower Albian (Baraboshkin, 1996, 2004; Casey, 1999). It seems likely that the Kj5 Member might also be attributed to the Early Albian. This assumption agrees with the proposed age of overlying and underlying strata (see above). The specimen of *Arcthoplites* is reposited in the University Museum, University of Tokyo (UMUT).

4. Systematic paleontology

Superfamily: Hoplitoidea H. Douvillé, 1890.
Family: Hoplitidae H. Douvillé, 1890.
Subfamily: Gastroplitinae Wright, 1952.
Genus: *Arcthoplites* Spath, 1925.
Subgenus: *Subarcthoplites* Casey, 1954.
Arcthoplites (*Subarcthoplites*) sp.

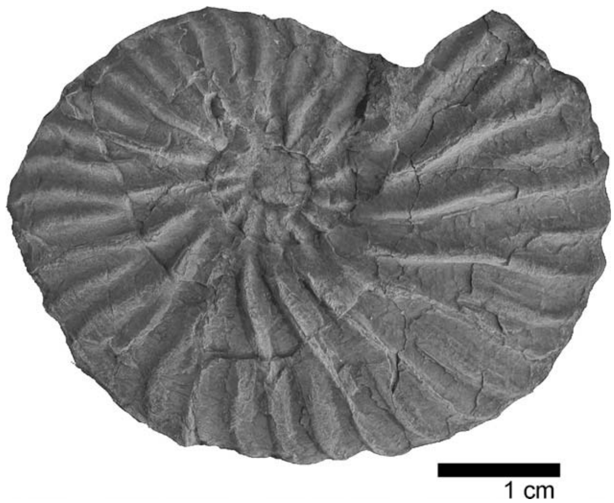

Fig. 2. Arctic-type ammonite *Arcthoplites* (*Subarcthoplites*) sp. UMUT MM 29217 from the Lower Albian of Kamiji Formation, Yezo Group, northern Hokakido, northern Japan.

4.1. Material

A single specimen, UMUT MM 29217 (Fig. 2) from the Chirashinaigawa Creek, Nakagawa area, northern Hokkaido, northern Japan.

4.2. Description

Shell 50.0 mm in diameter. Whorl flattened by compaction with the upper (left-side) flank missing. Whorls compressed with slightly inflated flanks, umbilicus moderately narrow (14.0 mm, umbilical diameter/shell diameter = 0.28) with sloping umbilical walls, and evenly rounded shoulder. Both primary and secondary ribs being present. The primaries well developed, weakly sigmoid and relatively high in cross-section. Primaries leave elongate swellings on the umbilical rim and some of them give rise to a secondary branch by bifurcation. Secondary ribs either arise freely at the middle level of flank between two primaries or split from the primary ribs. Points of branching raised into slight bullae. Eighteen primary ribs with 18 secondary ribs are present on the last whorl.

4.3. Remarks

The present species is similar to those of *Arcthoplites* (*Subarcthoplites*) *probus* Saveliev (1973), *A*. (*S.*) *talkeetnanus* Imlay (1960), *A*. (*S.*) *belli* McLearn (1945), and *A*. (*S.*) *bickeli* Imlay (1961) in the morphology of primaries and secondaries, their position of branching, closer ribbing, and a relatively compressed and involved shell-form. *A*. (*S.*) *probus* is known from the Lower Albian of the Russian Platform (Saveliev, 1973; Baraboshkin, 1996), *A*. (*S.*) *talkeetnanus* from the Lower Albian of Russian Far East and southern Alaska (Jones and Grantz, 1967; Alabushev, 1995), *A*. (*S.*) *belli* from the Lower Albian of Arctic Canada and northern Alaska (McLearn, 1945; Imlay, 1961), and *A*. (*S.*) *bickeli* from the Lower Albian of northern Alaska (Imlay, 1961). The primary and secondary ribs in the present species are not so flexuous than those in *A*. (*S.*) *probus*. *A*. (*S.*) *talkeetnanus* has relatively strong umbilical bullae (Jones and Grantz, 1967), but this feature does not appear in the present species. The present species differs from *A*. (*S.*) *belli* and *A*. (*S.*) *bickeli* in the absence of constrictions. Since there is some intraspecific variation in the pattern of ribbing during ontogeny of species of *Arcthoplites* (Saveliev, 1973; Jones and Grantz, 1967), more well-preserved specimens are required for exact species-level assignment of this species.

5. Paleobiogeographic and paleoclimatological implications

Arcthoplites has been the subject of much academic scrutiny with respect to its applications in Albian marine paleobiogeography and paleoenvironmental reconstructions (e.g., Birkelund and Håkansson, 1983; Baraboshkin, 1996; Casey, 1999). This genus is known to occur mainly in the Lower Albian *Leymeriella tardefurcata* Zone in Arctic–Boreal regions (Baraboshkin, 1996; Casey, 1999) (Fig. 3A). *Arcthoplites* s.s. was distributed in the Arctic, NW Europe, and Russian Platform and *Arcthoplites* (*Subarcthoplites*) in the Arctic, high latitudes of the North Pacific, and Russian Platform (Baraboshkin and Mikhailova, 2005). Since records of *Arcthoplites* are mainly restricted to the Arctic–Boreal regions, this genus represents an element of the typical Early Albian fauna. In the high latitudes of the North Pacific, species of *Arcthoplites* have been found in the Lower Albian *Brewericeras hulenense* Zone of southern Alaska and British Columbia (Jones et al., 1965; Jones and Grantz, 1967; McLearn, 1972), and in the Lower Albian *Arcthoplites talkeetnanus* Zone of the Korjak–Kamchatka region (Alabushev, 1995) (Fig. 3B).

The present latitude of the discussed *Arcthoplites* locality at the Nakagawa area in northern Hokkaido is about 44°N (Fig. 1). The Northeast Japan Tectonic Block, where the Yezo Group was deposited, was located further south during the Cretaceous period (e.g., Tazawa, 2004). Takashima et al. (2007) reviewed various data of the paleolatitude and the position of Early and mid-Cretaceous Hokkaido and other Japanese Islands, and suggested that northern Hokkaido reached 36°N (as a maximum southern estimate) in the Cretaceous. Thus, northern Hokakido was located at about 36–44°N in mid-Cretaceous and accounting for this estimation of locality at the Nakagawa area should be regarded as the southernmost record of *Arcthoplites* in the circum-North Pacific region (Fig. 3B). The occurrence of *Arcthoplites* in Hokkaido suggests that the southward distribution of the Arctic fauna transpired into the middle latitudes of the Early Albian North Pacific. The pre-Early Albian ammonite fauna in these latitudes of the Northwest Pacific generally correspond to that of the Tethyan Realm, except for the episodic occurrence of Boreal and/or high latitude elements: *Simbirskites* in the Early Barremian (Matsukawa, 1988; Obata and Matsukawa, 1988; Matsukawa and Obata, 1993). Furthermore, Arctic faunal elements have never been recognized in the post-Albian Cretaceous in middle latitudes of the North Pacific. Thus, it can be concluded that the Early Albian southward distribution of Arctic fauna in middle latitudes of Northwest Pacific was episodic.

An almost contemporaneous and profound faunal turnover took place in the Northwest Pacific during the Albian. Iba and Sano (2007) have recently documented a step-wise demise of the Tethyan biota during the latest Aptian to middle Albian in the Northwest Pacific. The tropical Cretaceous Tethyan biota, which are composed of two groups – Mesogean key taxa (e.g., rudists) and Mesogean indicators (e.g., orbitolinid foraminifers) *sensu* Masse (1992) – disappeared at the latest Aptian–Early Albian transition and at the Early Albian–middle Albian transition, respectively (Fig. 4). Since Mesogean key taxa inhabited a warmer environment than did Mesogean indicators (Masse, 1992), this faunal change suggests the occurrence of Early Albian "cooling" in the Northwest Pacific. The same pattern is also documented in the Kamiji Formation of the studied area, northern Hokkaido (Iba and Sano, 2006, 2007): i.e., Late Aptian Mesogean key taxa and indicators yielded from the lowest member of the formation Kj1 Member. Mesogean indicators (calcareous red algae) and non-rudist Tethyan bivalves were recovered from the Kj3 Member, but no fossils of Tethyan biota were found in the strata above the Kj3 Member (Fig. 1B).

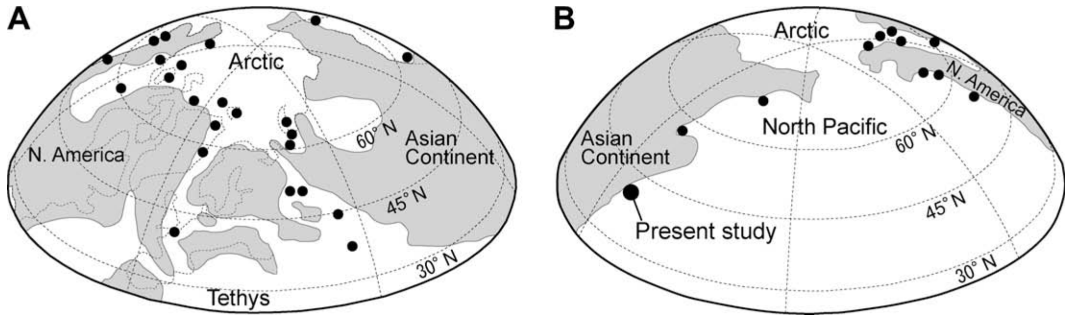

Fig. 3. Distribution of *Arcthoplites*. Black circles indicate the occurrences of *Arcthoplites*. Albian paleomaps modified from Barron (1987), Owen (1996), Eldridge et al. (2000), and Baraboshkin (2002). (A) Arctic–European regions (Birkelund and Håkansson, 1983; Casey, 1999). (B) North Pacific region (Jones and Grantz, 1967; McLearn, 1972; Alabushev, 1995; Yazykova, 2001).

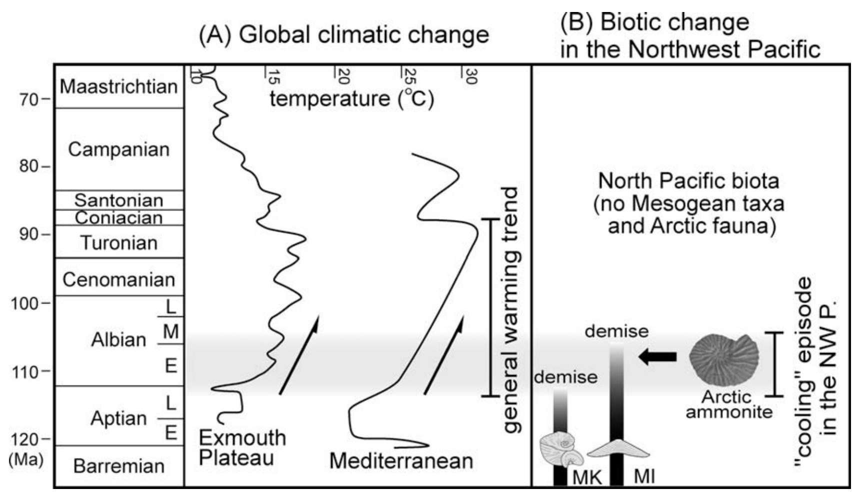

Fig. 4. Comparison of the Early Albian biotic change in the Northwest Pacific and the mid-Cretaceous global climatic change. Climatic changes based on Clarke and Jenkyns (1999) (Exmouth Plateau) and Steuber et al. (2005) (Mediterreanean). Albian step-wise demise of Mesogean taxa (tropical biota) in the Northwest Pacific based on Iba and Sano (2007). MK, Mesogean key taxa (e.g., rudists); MI, Mesogean indicator (e.g., orbitolinid foraminifers).

The occurrence of the Arctic-type ammonite *Arcthoplites* from the Kj5 Member of the Kamiji Formation, therefore, supports this "cooling" episode in the Early Albian Northwest Pacific (Fig. 4).

A significant global warming trend spanning from the Aptian to Turonian has been reconstructed from oxygen isotopic records of calcareous fine-fraction, bulk sediments, and rudist bivalve shells (e.g., Clarke and Jenkyns, 1999; Steuber et al., 2005). These studies show that oceanic temperature increased continuously during the Early Albian and reached a maximum in the Turonian (Fig. 4). However, paleobiogeographic data from the Northwest Pacific are not consistent with the general global warming trend, and probably indicate a distinct "cooling" episode in the mid-Cretaceous Greenhouse Earth (Fig. 4). Recently, a cooling phase in the latest Aptian–early Albian was reported in the North Sea region mainly on the basis of analysis of calcareous nannofossil assemblages (Mutterlose and Bornemann, 2005; Rückheim et al., 2006). These lines of evidence suggest that the climatic history of the mid-Cretaceous greenhouse period is much more complex than previously thought.

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