



Faunal turnover at the end of the Cretaceous in the North Pacific region: Implications from combined magnetostratigraphy and biostratigraphy of the Maastrichtian Senpohshi Formation in the eastern Hokkaido Island, northern Japan

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ABSTRACT

A combined magnetostratigraphic and biostratigraphic study has been performed on the Maastrichtian Senpohshi Formation in eastern Hokkaido Island, northern Japan, which is an approximately 1300 m thick section mainly composed of hemipelagic mudstone. The identification of magnetic polarity was possible at 51 horizons, whereby four magnetozones were recognized. These magnetozones were correlatable to geomagnetic polarity chrons C31r to C30n, suggesting that the age of the Senpohshi Formation is spanning from middle to upper part of the Maastrichtian (ca. 69–67 Ma).

The magnetostratigraphy of the Senpohshi Formation established in this study enables a direct age correlation to the Maastrichtian successions in other regions. Thus, this detailed chronology of the formation contributes to paleontological studies of the Maastrichtian in the North Pacific region. For instance, this magnetostratigraphic age assessment implies the following: (1) the stratigraphic range of the ammonite *Pachydiscus flexuosus* contains polarity chrons from the lower part of C31r to the lower part of C31n, (2) the first occurrence (FO) of the calcareous nannofossil *Nephrolithus frequens* in the North Pacific region is correlatable to polarity chron C30n or below, and (3) the FO of the bivalve "*Inoceramus*" *awajiensis* is located within polarity chrons from C31r to the upper part of C31n. This suggests that the inoceramid extinction event in the North Pacific region might have occurred during polarity chrons from C31r to the upper part of C31n (ca. 70.5–67.8 Ma), which is 2.3–5.0 Myr prior to the Cretaceous/Paleogene boundary. The trend of the Maastrichtian faunal turnover in the North Pacific is well consistent with those of other regions, brings a new evidence for understanding the global faunal turnover in the Maastrichtian, just before Cretaceous/Paleogene mass extinction.

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1. Introduction

The Maastrichtian (ca. 70.6–65.5 Ma) is the geological stage that spans the last 5 Myr of the Cretaceous period (Ogg et al., 2004) just before the mass extinction event at the Cretaceous/Paleogene boundary (commonly known as K/T boundary). It has been generally believed that the K/T mass extinction event was catastrophic (e.g., D'Hondt et al., 1996; Marshall and Ward, 1996; Pospichal, 1996) and an extraterrestrial impact was the cause of the event (e.g. Alvarez et al., 1980), though controversy is still continuing about the timing of the bolide impact and its relationship with the mass extinction event (Keller et al., 2007, 2008; Schulze et al., 2008). On the other hand, it is widely known that extensive environmental changes had occurred during the Maastrichtian. For example, some second-order regres-

sions superimposed on the long-term sea-level fall was reported (Haq et al., 1987). Many studies also reported the widespread cooling (e.g., Barrera and Savin, 1999; Frank and Arthur, 1999; Huber et al., 2002), whereas North Atlantic warmed during the Maastrichtian (MacLeod et al., 2005; Isaza-Londoño et al., 2006). Furthermore, changes in thermohaline circulation occurred in the mid-Maastrichtian, though there is disagreement on the mechanism and character of the event (MacLeod and Huber, 1996; Barrera et al., 1997; Barrera and Savin, 1999; Frank and Arthur, 1999; MacLeod et al., 2000; Frank et al., 2005).

These environmental changes seemed to cause the significant faunal turnovers. In the mid-Maastrichtian, widespread bivalve inoceramids had been extinct (Ward et al., 1991; MacLeod et al., 1996), and rudistid reef in the tropical region collapsed (Johnson and Kuffman, 1990, 1996; Johnson et al., 1996). Moreover, some calcareous plankton (calcareous nannofossil *Nephrolithus frequens* and planktonic foraminifera *Abathomphalus mayaroensis*) showed latitudinal migrations in the mid-Maastrichtian (Pospichal and Wise, 1990; Huber,

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1992; Huber and Watkins, 1992). These environmental and faunal changes were called the “mid-Maastrichtian event” (MME). An important feature of the MME is that the faunal turnovers were diachronous throughout the world; it is suggested that inoceramid extinction and first occurrences of *N. frequens* and *A. mayaroensis* are earlier in the southern high latitudes and later in equatorial and northern hemisphere (Pospichal and Wise, 1990; Huber, 1992; Huber and Watkins, 1992; MacLeod et al., 1996). It is considered that sea-level fall, climate cooling, and changes in thermohaline circulation played important roles in this faunal event (Huber and Watkins, 1992; Johnson et al., 1996; MacLeod and Huber, 1996). Therefore, the Maastrichtian faunal and environmental changes had a close relationship, and it is important to understand them because they provide background information for the K/T mass extinction event.

However, the details of the global Maastrichtian faunal and environmental changes are not understood very well, particularly as there are few data from the North Pacific region, because of the few continuous, well-dated Maastrichtian successions in this region. There are only two relatively well-studied Maastrichtian successions in the Pacific Northwest – the Hakobuchi Formation in the Nakatonbetsu area of northern Hokkaido Island, northern Japan, and the Krasnoyarka Formation in the Naiba area of southern Sakhalin, Russia (Fig. 1). Although the Hakobuchi Formation yields abundant megafossils, the strata corresponding to the uppermost part of the Maastrichtian is missing due to unconformity (Ando et al., 2001; Ando and Tomosugi, 2005). Moreover, precise age determination of the Hakobuchi Formation is difficult because most of the index fossils show provinciality. On the other hand, a magnetostratigraphic study of the Krasnoyarka Formation has revealed that it includes the uppermost part of the Maastrichtian, even though the K/T boundary was not recognized (Kodama et al., 2000, 2002). The

stable carbon isotope stratigraphy of the Krasnoyarka Formation was also proposed (Hasegawa et al., 2003). However, due to the absence of megafossils in the Upper Maastrichtian of the Krasnoyarka Formation (Kodama et al., 2002), one can obtain less information of the faunal turnover in the Upper Maastrichtian from the formation. Therefore, in order to improve the database about the Maastrichtian faunal turnover, it is important to give attention to other good sections in the North Pacific region. We thus focused on the Maastrichtian Senpohshi Formation in eastern Hokkaido Island, northern Japan, which exhibits excellent exposure of hemipelagic mudstone deposited under a stable sedimentary environment. The Senpohshi Formation yields Maastrichtian megafossils and microfossils, though most of them are endemic (Toshimitsu et al., 1995). Therefore, in order to make a global stratigraphic correlation possible, we performed a magnetostratigraphic study to assess the precise and detailed chronologic assignment of the formation. On the basis of our magnetostratigraphic correlation, we reconsider the biostratigraphic zonation of the Upper Maastrichtian in the North Pacific region and estimate the chronostratigraphic timing of the first occurrence of the calcareous nannofossil *Nephrolithus frequens* and the inoceramid extinction event.

2. Geological setting

The Senpohshi Formation belongs to the Cretaceous–Paleogene Nemuro Group distributed in eastern Hokkaido Island, northern Japan (Fig. 1). The Nemuro Group is mainly composed of hemipelagic mudstones and sediment gravity flow deposits such as turbidites and submarine slump deposits (Kiminami, 1978; Naruse, 2003), and the Nemuro Group is interpreted as deposits in the forearc basin off the Kuril arc (Kiminami, 1983).

The Senpohshi Formation is extensively exposed along the western coast of Akkeshi Bay in eastern Hokkaido Island (Fig. 2), conformably overlying the Oborogawa Formation and unconformably overlain by the Shiomi Formation (Asano, 1962; Okada et al., 1987). Structurally, the Senpohshi Formation exhibits homoclinal bedding in the E–W direction and gently dips 10–20° southward. The thickness of the formation is greater than 1270 m, although its upper boundary is not exposed. No large-scale fault and tectonic folding are recognized. The formation mainly consists of weakly bioturbated, dark gray mudstone (Fig. 3). The mudstone layers are occasionally intercalated with sandstone laminae or thin beds (~1.0 cm) that can be interpreted as sediment gravity flow deposits. Thin slump deposits occur in some horizons.

3. Fossil occurrence and biostratigraphy

Megafossils and microfossils reported in the Senpohshi Formation, though not abundant, indicate Maastrichtian (Fig. 3). Naruse et al. (2000) have reported the occurrence of the ammonite *Pachydiscus flexuosus* in the lower part of the formation, which is widely distributed in Maastrichtian successions throughout southern Sakhalin and Hokkaido Island (Maeda and Shigeta, 2005; Maeda et al., 2005). Okada et al. (1987) have reported the occurrence of the calcareous nannofossil *Nephrolithus frequens*, an index fossil of the Upper Maastrichtian (Burnett, 1998), in the upper part of the formation. Moreover, planktonic foraminifera *Globotruncanella petaloidea*, which indicates the Maastrichtian (Caron, 1985), was reported to occur in the upper part of the formation (Yamada, 1984).

In this study, the following megafossils were newly discovered (Fig. 3, Plate I): the ammonite *Pachydiscus flexuosus* (Loc. FS01) and the bivalve “*Inoceramus*” *awajiensis* (Loc. FS02). Both megafossils occur in the lower to middle part of the formation, and they are preserved in calcareous concretions. *P. flexuosus* occurs in the Maastrichtian sections in the Pacific Northwest (Toshimitsu et al., 1995; Maeda and Shigeta, 2005; Maeda et al., 2005). “*I.*” *awajiensis*, which may be

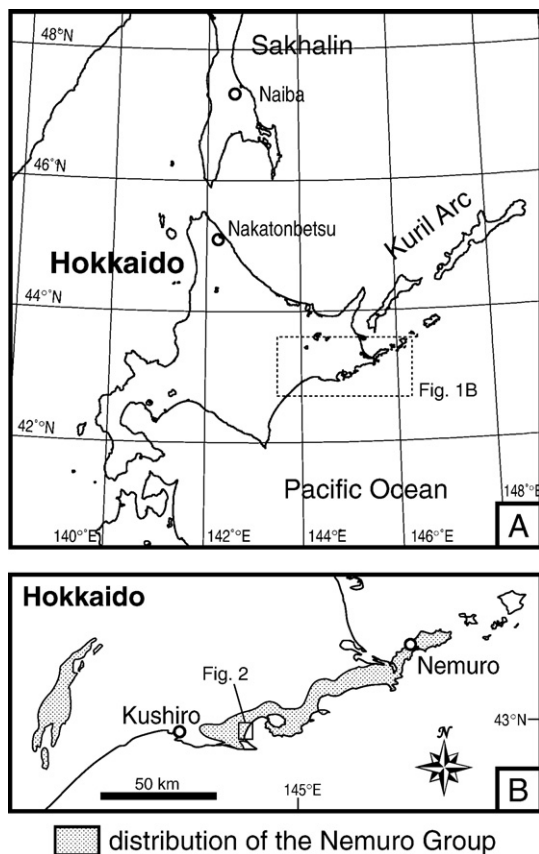


Fig. 1. Index maps showing location of Hokkaido Island (A), and distribution of the Nemuro Group (B). The square in B indicates the study area (refer to Fig. 2).

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