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Planktonic foraminiferal biostratigraphy and assemblages in the Bering Sea during the Pliocene and Pleistocene: IODP sites U1340 and U1343

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ABSTRACT

IODP Site U1340 and Site U1343 in the Bering Sea have been investigated with regard to planktonic foraminifers and fragmentation. The base of Site U1340 dates back to the Early Pliocene and the base of Site U1343 to the Early Pleistocene. Site U1340 is situated at Bowers Ridge, the southern Bering Sea. Site U1343 is situated near the gateway to the Arctic Ocean in the northern Bering Sea. At both sites there are none or very few planktonic foraminifers during the Pliocene and early Pleistocene. After 1.3–1.4 Ma the planktonic foraminifers are continuously present for most of the samples examined. Three stratigraphic events have been identified in this study. The first occurrence (FO) of *Neogloboquadrina inglei* is observed at 1.4–1.5 Ma, although this event may be affected by poor preservation of foraminifers in older sediments. The observed age of the change in the coiling ratio of *Neogloboquadrina pachyderma* from right to left at 1.2 Ma agrees with the dating of the same event at the Californian margin. The age of the last occurrence (LO) of *N. inglei* also seems to match the same event from the Californian margin at 0.7 Ma. This implies that these events are robust regional events for the entire northern Pacific. Multivariate analyses of the quantitative planktonic foraminifer data show three main faunal assemblages. The oldest assemblage from 1.3–1.4 Ma to 1.2 Ma is dominated by *N pachyderma* s.l. (dex) together with *Globigerina bulloides*. Other species in this fauna are *N. inglei*, *N. pachyderma* s.l. (sin), *Globigerina umbilicata* and *Turborotalita quinqueloba.* After 1.2 Ma the faunal assemblage is dominated by *N. pachyderma* s.l. (sin), but the remaining species are the same as before. At 0.7 Ma *N. inglei* disappears, whilst the remaining fauna assemblage stays the same, with *N. pachyderma* s.l. (sin) still dominating, reflecting subpolar–polar conditions. Prior to 1.4–1.3 Ma there are very few or no planktonic foraminifers. Low shell fragmentation and lower TOC suggest that the lack of planktonic foraminifers in these sediments cannot be explained either by a shoaling of the carbonate compensation depth or by enhanced supralysoclinal dissolution. Instead, we argue that the appearance of abundant foraminifers in the sediment reflects the same evolutionary adaption of *N. pachyderma* (sin) to cold conditions to have occurred after 1.1–1.0 Ma as in the North Atlantic.

1. Introduction

In 2009 the Integrated Ocean Drilling Program (IODP) carried out Expedition 323 in the Bering Sea (Fig. 1). One of the main objectives of the expedition was to study the evolution of Pliocene–Pleistocene surface water conditions. The long term evolution of surface water masses and sea-ice distribution in the Bering Sea is poorly understood yet significant for understanding the processes ruling ocean–climate interactions (Takahashi et al., 2009). Microfossils, fossil micro fauna and flora, have proven to be good tracers of surface water masses and sea-ice elucidating past ocean–climate changes. During IODP Expedition 323 several microfossil groups were recovered; diatoms, silicoflagellates, ebridians, radiolarians, dinoflagellates, calcareous nannofossils, ostracods, and benthic foraminifers in addition to planktonic foraminifers (Takahashi et al., 2011). Planktonic foraminifers differ from the most abundant microfossil groups found during IODP Expedition 323 by having a calcareous test. Furthermore, planktonic foraminifers inhabit a wider range of depths in the surface ocean, including depths below the photic zone (Hemleben et al., 1989); hence unlike the microfossil groups, which live in the uppermost part of the water column, planktonic foraminifers may reflect subsurface water conditions.

Plio-Pleistocene planktonic foraminifers from the Bering Sea were first studied during the Deep Sea Drilling Project (DSDP) Leg 19 in 1971 (Creager and Scholl, 1973). Only very few planktonic foraminifers were found preserved in the Pliocene sediments, conversely the frequency increased in the Pleistocene enabling better certainty in

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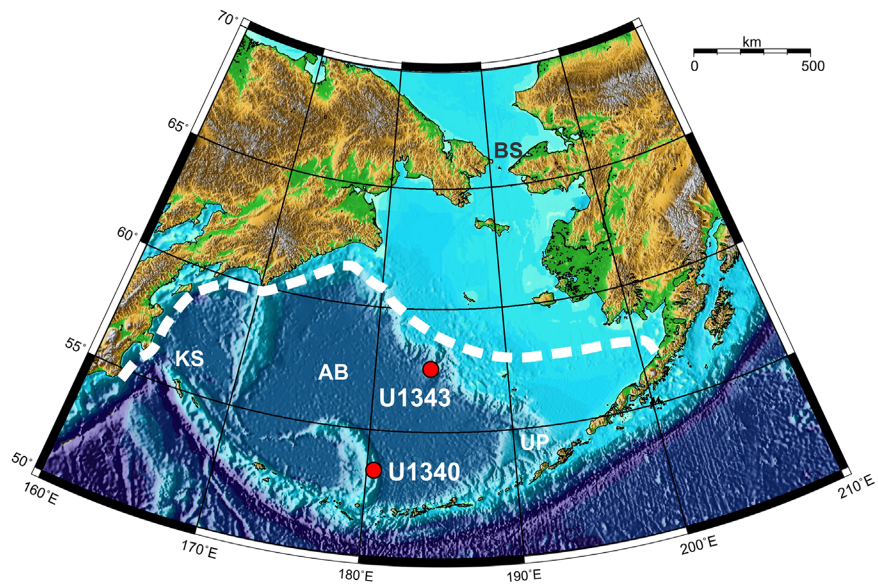

Fig. 1. Bathymetric map with core locations. KS = Kamchatka Strait. AB = Aleutian Basin. UP = Umnak Plateau. BS = Bering Strait. The white dashed line indicates the modern day sea-ice boundary.

paleoclimatic interpretations (Echols, 1973). The same distribution pattern was also observed in all drilled sites during the 2009 expedition in the Bering Sea (Takahashi et al., 2011). However, the planktonic foraminifers were only investigated qualitatively during both expeditions. This study aims to improve the resolution of the shipboard investigations and provide a detailed Plio-Pleistocene planktonic foraminiferal biostratigraphy from the Bering Sea, describe the quantitative development of faunal assemblages and assess the influence of carbonate dissolution on the planktonic foraminiferal record.

1.1. The modern Bering Sea

The Bering Sea is a semi-enclosed marginal sea of the North Pacific connected to the Arctic Ocean through the shallow Bering Strait (Fig. 1). The Bering Sea comprises a broad shelf with water depths less than 200 m and a deep basin almost 4000 m deep (Hood, 1983). The northern continental shelf is seasonally covered by sea-ice, while other parts of the Bering Sea are rarely covered by sea-ice (Niebauer and Day, 1989). Oceanographically, the Bering Sea can be considered as a continuation of the North Pacific subarctic gyre, which is a part of the eastward warm water flow in the Pacific Ocean (Karl, 1999). The Alaskan Stream flows into the eastern Bering Sea, moving counter-clockwise around the basin as the Bering Slope Current along slope between the shallow Umnak Plateau and the deep Aleutian Basin, and exiting through Kamchatka Strait (Fig. 1). There is also a northward flow in the Bering Sea, which exits through the Bering Strait (Fig. 1). This northward flow provides the only connection and exchange of waters between the Pacific and Atlantic Oceans in the Northern Hemisphere. During sea-ice formation, cold saline water (>34 psu and <-1.5 °C) is produced over the northern shelf and flows northward through the Bering Strait. Globally, this water plays a role both in maintaining the Arctic Ocean halocline and in ventilation of the deep waters (Aagaard et al., 1985).

2. Material and methods

2.1. Study sites and core material

The study is based on material from Holes U1340A and U1343E. Site U1340 is situated at Bowers Ridge, the southern Bering Sea, under the axis of the Alaskan Stream transporting warm water into the Bering Sea at 1313 m water depth. Site U1343, is situated close to the gateway to the Arctic Ocean at 2000 m water depth in the northern Bering Sea close to the present seasonal sea-ice limit (Fig. 1). The sediments in Hole U1340A are diatom ooze and diatomaceous silt with minor amounts of foraminifers and other microfossils (Takahashi et al., 2011). In Hole U1343E the sediments consist mainly of silt with varying amounts of clay and diatoms in addition to minor amounts of foraminifers and other microfossils (Takahashi et al., 2011). The recovered core length of Hole U1340A is 535.89 m, and 103 sediment samples were collected during the expedition (2 samples/core). For Hole U1343E the recovered core length is 700.27 m, and 151 sediment samples were collected during the expedition (2 samples/core).

2.2. Stratigraphy and age models

Combined biostratigraphy and magnetostratigraphy show that Pliocene to recent sediments were recovered at Site U1340 with no apparent hiatuses (Takahashi et al., 2011). Biostratigraphic datums and magnetochron ages were used to develop an age model by linear interpolation (Takahashi et al., 2011) (Table 1). The lowermost part of Site U1340 shows a relatively low sedimentation rate of 3 cm/kyr but it increases to 32 cm/kyr. This value decreases upwards to 11 cm/kyr (Table 1). Site U1343 spans the Late Pliocene to Recent (Takahashi et al., 2011). The chronological framework of Site U1343 is based on oxygen isotope stratigraphy (Asahi et al., 2016), and sedimentation rates are generally high (average 36 cm/kyr) (Table 1). Geological epochs and ages follow the definitions by Gradstein et al. (2012) with the Pliocene–Pleistocene boundary at 2.588 Ma.

2.3. Analytical methods

The foraminiferal samples were frozen, freeze-dried and wet sieved at the size fractions 1 mm, 100 μm and 63 μm. Subsequently the samples were dried at room temperature and counted at the size fraction larger than 125 μm size fraction. This size fraction was chosen in order to enable comparisons with studies of modern planktonic foraminifers in the Bering Sea (Asahi and Takahashi, 2007). At least 300 specimens were identified to species level and counted. Planktonic foraminiferal taxonomy