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# Orbital and millennium scale environmental changes in the southern Bering Sea during the last glacial-Holocene: Geochemical and paleontological evidence

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**Abstract**

The $\delta^{18}$O benthic foraminiferal curve and AMS $^{14}$C radiocarbon data provide a representative age model for a southern Bering Sea sediment core (GC-11). Downcore profiles of $\delta^{18}$O of *N. pachyderma* (s.) and *U. auberiana,* carbonate and organic carbon contents, species changes in the planktonic foraminifera assemblages and some diatom species show orbital (MIS 1, 2 and 3) and millennium scale variability influenced by the Alaska Current flowing into the studied region. Three warmer episodes in the southern Bering Sea environment were assumed to be synchronous with DO interstadials 8, 12 and 14 (in GISP-2 chronology) during MIS 3. More severe climate and environmental conditions in the southern Bering Sea during MIS 2 occurred synchronously with the LGM within a 17–19 ka time span. Two well pronounced environmental warming events, productivity spikes and changes in the pore water geochemistry, separated by Younger Dryas cooling, were observed at the base of MIS 1 coeval with MWP 1A and 1B. Regional glacial primary productivity based on the calculation of the organic carbon MAR, similar to that found in the far northwestern Pacific, exceeded the Late Holocene values under conditions close to the present day.
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## 1. Introduction

The complex analysis of oxygen and carbon stable isotopes, geochemical, lithological, and micropaleontological characteristics of Upper Quaternary sediments in the Okhotsk and Bering Seas (Gorbarenko, 1996) shows that these marginal sea basins were characterized by extremely intricate hydrological and climatic history during the last glacial period and Holocene. The Quaternary oceanography of these two marginal basins and

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adjacent ocean remain insufficiently studied so far, although they cover wide areas and influence substantially the hydrology of the North Pacific. This is to a large extent explained by the high CCD level in these basins and, correspondingly, by the low contents of calcareous microfossils in the sediments, which serve as a basis for the chronological scale and paleoceanographic reconstruction.

The recent multiproxy studies of the Sea of Okhotsk have shown that significant progress has been made in the chronostratigraphy of the Late Quaternary sediments and evolution of the sedimentation, hydrology, ice covering and productivity (Gorbarenko, 1996; Gorbarenko et al., 1998, 2002a; Chekhovskaya and Basov, 1999; Khusid and Basov, 1999; Shiga and Koizumi, 2000; Chekhovskaya et al., 2001).

As a result of the detailed multiproxy study of ODP Site 883 in the northwestern Pacific, representing an end chain in the global thermohaline conveyor, millennium scale cycles during MIS 3 were established in the far NW Pacific (Kiefer et al., 2001). In their opinion, these cycles occurred in antiphase with the DO stadials in Greenland and the North Atlantic. The authors estimated changes in the surface water temperature based on variations in the composition of planktonic foraminiferal assemblages. Simultaneously, other studies revealed suborbital variations in surface water parameters and water ventilation in the northeastern Pacific (ODP Site 893) synchronous with the DO stadials in Greenland and the North Atlantic (Hendy and Kennett, 2000).

Studies of the composition and ecological characteristics of diatom assemblages (Jousé, 1962; Sancetta, 1982; Sancetta and Robinson, 1983; Sancetta et al., 1985) have revealed a highly variable surface environment and hydrological structure of the Bering Sea during the Late Quaternary. However, the planktonic foraminifers in Late Quaternary Bering Sea sediments, which can be reliably dated by geochronological methods, were never studied.

Thus, we carried out a multiproxy study of the Upper Quaternary sediments from the southern part of the Bering Sea, the hydrological conditions of which are to a significant extent controlled by inflowing Pacific waters. Orbital and millennium-scale regional paleoenvironmental changes were studied by isotope–geochemical and paleontological methods, paying special attention to the construction of the age scale and ecological changes in the planktonic foraminiferal assemblages.

## 2. Material and methods

Core GC-11 (635 cm long) was taken in 1991 during Cruise 19 of the R.V. *Akademik Aleksandr Vinogradov* at the foot of the western slope of Bowers Ridge (53°31′N, 178°51′E, water depth of 3600 m, Fig. 1). The sediment lithology is as follows: 0–13 cm grayish brown (5YR3/2) silty clay with sand including agglutinated benthic foraminifera, ash layer at 95 cm; 13–111 cm—diatomaceous olive gray (5Y5/2) soft silty clay with foraminifera admixture; 111–123 cm—olive gray silt with sand admixture; 123–161 cm—diatomaceous grayish olive soft silty clay with foraminifera admixture; 161–230 cm—dark olive gray (5G4/1) soft terrigenous silt; 230–457 cm—hard terrigenous dark olive gray silt, pebbles and rubbles at 263 and 340 cm. Tephra admixture at 395 and 405 cm; 457–462 cm—gray silt with foraminifera admixture; 462–510 cm—weakly diatomaceous silty clay with foraminifera admixture in the lower part; 510–530 cm—terrigenous silt with sand admixture; 530–645 cm—silty olive gray clay weakly diatomaceous, 645–660 cm—olive-gray green sandy silt.

Oxygen isotopes in planktonic and benthic foraminifera were measured on a modified VG mass spectrometer according to previously described methods (Keigwin, 1998) in the laboratory of Dr. L.D. Keigwin (Woods Hole Oceanographic Institution, USA). The analyses were performed on the benthic species *Uvigerina auberiana* (2–4 specimens) from the 250 to 350 μm fraction and on the planktonic species *Neogloboquadrina pachyderma* sinistral (s.) (15–20 specimens) from the 125 to 250 μm fraction without preliminary roasting.

$CaCO_3$ and total organic carbon content (TOC) were measured by coulometry using an AN-7529 analyser (Gorbarenko et al., 1998).

*N. pachyderma* (s.) and *U. auberiana* foraminifera between fractions 125–250 μm to 250–350 μm, respectively (weight 2–4 mg), were dated by accelerator mass spectrometry (AMS) at the Lawrence Livermore National Laboratory.

Samples taken from 1-cm-thick slices at 5 cm intervals were examined for planktonic foraminifers. Foraminiferal tests were counted in the fraction of > 100 μm separated from 40–60 g of dry sediment. Depending on abundance, between 70–150 and 200–450 specimens were counted in

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