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Seasonal temperature fluctuations in the high northern latitudes during the Cretaceous Period: isotopic evidence from Albian and Coniacian shallow-water invertebrates of the Talovka River Basin, Koryak Upland, Russian Far East

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Abstract

Palaeotemperatures during the Albian–Coniacian in the northernmost Pacific have been determined on the basis of oxygen isotopic analysis of well-preserved brachiopod and molluscan shells from the Koryak Upland, Far East Russia. Those obtained from the calcitic brachiopod shells from the Albian range from 12.5 to 22.7 °C. The lower temperature level corresponds to winter seasons and the higher reflects summer temperatures. Probable winter isotopic palaeotemperatures, fluctuating from 10.9 to about 14.1 °C, were obtained from Coniacian bivalve shells. Presumed spring and autumn isotopic palaeotemperatures for the Coniacian, fluctuating from 14.1 to 17.7 °C, were obtained from rhynchonellid brachiopods and bivalves, all with calcitic shells, and ammonoids with aragonitic shells. Presumed summer isotopic palaeotemperatures varied between 18.5 °C to 22.4 °C. The new and previously published data suggest a short-term presence of polar ice during the Cretaceous (early Maastrichtian) only in the Southern Hemisphere on the Antarctic continent. Evidence pertaining to the Northern Hemisphere seems to suggest only occasional short-lived subfreezing conditions. These most probably occurred during polar winters in the early Valanginian, late Coniacian–early Santonian and early Maastrichtian. Temperatures in northern high latitudes during the course of even these winter seasons were probably not low enough for the formation of permanent sea ice. This may be a result of the lack of a continental massif in the North Pole area and a significant ameliorating effect of oceanic heat-transport poleward through the straits of Turgai and the Western Interior of North America.

Keywords: Cretaceous; Oxygen isotopes; Carbon isotopes; Seasonal palaeotemperatures; Palaeoproductivity; Palaeosalinity; Invertebrates; Talovka; Koryak Upland

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1. Introduction

According to Price (1999), throughout the Mesozoic Era high-latitude warmth was the norm, although limited polar ice at times is not a myth but was a reality. Barerra et al. (1987) and Barerra (1994) have provided proof of rather low late Campanian–Maastrichtian water temperatures for both the Seymour Island shelf (Antarctica) (ca. 4–9 °C) and the equatorial Pacific deep-sea sites (ca. 7–14 °C) based upon isotope data on benthic foraminifera. The existence of low temperatures in southern high latitudes during the early Maastrichtian was recently confirmed by the isotopic investigation of Huber et al. (1995) of planktic foraminifera [10 °C; pH effect on foraminiferal $\delta^{18}O$ (Zeebe, 2001) not taken into account]. Similar evidence has been obtained from Maastrichtian macrofauna of James Ross Island, Antarctica (Pirrie and Marshall, 1990): 9.32–14.84 °C (from bivalves), 10.61–14.81 °C (from nautiloids), 9.93–12.35 °C (from ammonoids: *Gunnarites*), 10.17 °C (from a belemnite rostrum).

Recently Miller et al. (1999) have established the coincidence of $\delta^{18}O$ increases in both Maastrichtian deep-water benthic foraminifera of the Antarctic, South Atlantic and Indian-Pacific basins, and Maastrichtian low-latitude surface-dwelling planktic foraminifera of the Pacific, by comparison with Late Campanian foraminifera. They put forward two interpretations to account for the coincidence of these events: (1) the development of a moderate-sized ice sheet during the early Maastrichtian, and (2) a global decrease in both deep and tropical sea-surface temperatures during this period. Since the events mentioned above correlate with a large (30–40 m), rapid, earliest Maastrichtian sea-level fall, inferred from the New Jersey sequence-stratigraphic record, they incline mainly to the first interpretation, supporting a glacio-eustatic cause for the sea-level lowering.

Lowermost isotopic palaeotemperatures for Cretaceous northern high latitudes (5.3–10.4 °C) (Ditchfield, 1997) have been obtained from early Valanginian belemnite rostra of Svalbard; relatively low isotopic palaeotemperatures for the Maastrichtian (10.2–16.9 °C) have been recently obtained by us from early Maastrichtian brachiopods of the western Koryak Upland (Zakharov et al., 2000).

We focus in this paper on palaeotemperature fluctuations in high latitudes of the Northern Hemisphere during the Albian–Coniacian to distinguish lowermost (winter) temperatures for this time interval.

2. Material and methods

Macrofossil samples for isotope analyses were collected by a Russian-Japanese Geological Expedition team in 1999 from the Talovka River Basin, western Koryak Upland, northern Kamchatka (Fig. 1). During the Barremian–Paleogene this basin was at a palaeolatitude of approximately 69° N (Spicer et al., 2002). Material used for isotopic analysis consisted of: (1) brachiopod shells with fibrous structure from the Albian Kedrovskaya Formation along the Melkaya River (6 samples); (2) aragonitic and calcitic inoceramid shell material from the Cenomanian Mamet Formation of the right bank of the Talovka River (10 samples); and (3) exceptionally well-preserved shells of brachiopods, bivalves, gastropods and diverse ammonoids from the Coniacian Penzhinskaya Formation exposed along the lower reaches of the Talovka River (87 samples). Some Coniacian mollusc shells from Hokkaido, which retain original mineralogy and microstructure, were also investigated.

Zolotarev et al. (1974) and Evseev et al. (1999) recognized seasonal layers in shells of the Recent bivalves *Swiftopecten swifti* (Bernardi) and *Mizuhopecten yessoensis* (Jay) from the Sea of Japan. Only a single cycle of temperature fluctuation was discovered within each annual shell layer of *Swiftopecten swifti*, indicated on the surface of the shell by steep ridges (Fig. 2). Zolotarev et al. (1974) determined that the formation of ridges in this species is initiated by increased (fairly warm) temperatures at the beginning of the summer (12–16 °C), and that the first stage in the formation of wide bands (growth increments) occur at the maximum temperature (25.5 °C). Maximum linear growth of shells under the influence of the highest summer temperatures is about 2 mm during 1–2 weeks. Subsequent formation of annual layers in the autumn and winter takes place under the gradual lowering of temperature (to 4.5 °C). No pronounced morphological indicators, corresponding to the coldest seasons, are present on the shell surface; completion of growth of each wide band takes place in the spring.

Samples for our isotopic analyses were carefully removed from the shells using a special method. Material was taken from narrow areas along growth striations on the surface of the shell that crossed all shell layers except the innermost, covering all living chambers in ammonoids and gastropods, and the inner surface of brachiopod and bivalve valves. This enabled shell material formed during different seasons of the year to be identified.

The following were used to determine diagenetic alteration in the organogenic carbonates investigated: (1) visual signs; (2) percentage of aragonite in a structure when analyzing shells originally composed of 100% aragonite; (3) degree of integrity of microstructure, determined under a scanning electron microscope (SEM) when ammonoid aragonite was investigated, and by a preliminary luminescent test using a JXA-5A microanalyzer when calcitic brachiopod shells were examined.