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The effects of glacio-eustatic sea-level change on Pleistocene cold-water ostracod assemblages from the Japan Sea

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Abstract

The Pleistocene palaeo-habitats and the extinction history of cold-water ostracods in the Japan Sea are recorded in its coastal strata. The presence of now-extinct species in the Omma Formation of central Japan (1.5 Ma) indicates that such species predominated in a shallow, open sea environment. The tolerance ranges of these species as to water temperature and salinity are inferred to have been narrower than those of most extant cold-water species in the same families that live in shallow open water, as well as in brackish inner bays. The horizons in the Omma Formation with peak relative abundances of now-extinct species differ from the horizons with peak abundances of living Japan Sea species. We therefore suggest that the now-extinct species were adapted to optimum temperature and salinity conditions that differ from those in the modern Japan Sea. The observation that few now-extinct species survived after 0.4 Ma may be explained by the hypothesis that physicochemical properties of the water masses changed. We argue that, during the glacial periods with increased amplitude (0.9–0.4 Ma), the salinity decreased as the result of glacio-eustatic changes and the closure of shallow straits owing to low sea levels, causing the extinctions.
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Keywords: ostracods; extinction; Pleistocene; glacio-eustatic sea-level change; Japan Sea; water mass

1. Introduction

Investigations into the effects of Quaternary climate change on global biodiversity and ecosystems have yielded key insights for modeling the potential impact of future human-induced climate change in the world's biota (e.g., Cronin, 1999; Cronin et al., 1999). Studying the biotic responses of past faunas related to climatic fluctuations is useful for predicting extinctions and survival in response to possible future climatic changes and has become increasingly important (Roy et al., 1995; Cronin and Raymo, 1997; Cannariato et al., 1999).

The Japan Sea is well suited to this type of study because it is a semiclosed, mid-latitude (35–45°N), marginal sea which was strongly influenced by Quaternary glacio-eustatic sea-level fluctuations linked to global climatic oscillations (e.g., Tada,

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1994; Kitamura et al., 2001). The Tsushima Warm Current, a branch of the northward-flowing Kuroshio Current, transports a large amount of heat and countless marine organisms from the south towards the north and dominates the present-day oceanography of the Japan Sea (Nishimura, 1966; Ikeya and Suzuki, 1992; Tsuchida and Hayashi, 1994). During the Pleistocene glacial periods, sea level was low, and the water temperature and salinity in shallow areas were lower than today's due to a reduced influx of warm water from the south. There have been few studies comparing recent and pre-Holocene faunas and differences in water masses within the Japan Sea. Benthic ostracods (Crustacea) are ideal for such studies because they are extremely sensitive to environmental changes and are abundant in both Quaternary strata and modern surface sediments (Okada, 1979; Irizuki, 1993; Ozawa and Kamiya, 2001; Ozawa, 2003a).

The term "Omma–Manganji fauna" was originally applied to Pliocene cold-water molluscs of central and northeastern Japan (Otuka, 1939; Chinzei, 1978). The "Omma–Manganji ostracods" (Cronin and Ikeya, 1987) belong to a characteristic, Japan Sea benthic fauna with a high diversity of endemic species (Irizuki, 1989; Cronin et al., 1994; Ozawa, 1996, 2003b). The ostracods are called cold-water or cold-current species (e.g., Okada, 1979). Many of them are thought to have dwelled in shallow cold-water areas during periods of low sea level (i.e., glacial periods) because they belong to genera that presently live in areas to the north of the Japan Sea (Tabuki, 1986). This ostracod fauna contains many species in several families, which are considered to have become extinct during the Pleistocene (e.g., Ozawa, 2001), but little is known of the detailed history of their extinction and survival. In fact, there have been few studies of the extinction of ostracod species in other regions during the Quaternary and not only in the Japan Sea.

Our goal is to understand the relationship between the extinction–survival of benthic marine species based on Japan Sea ostracods and the fluctuations of oceanic environments in response to glacio-eustatic sea-level changes since the early Pleistocene in this region of the northwestern Pacific.

2. Japan Sea ostracods and water masses

The Tsushima Warm Current is the only ocean current entering the modern Japan Sea from the south (Fig. 1A), and it determines its modern water mass structure, with ostracod fauna living in several distinct water masses (Ozawa, 2003a). This author described

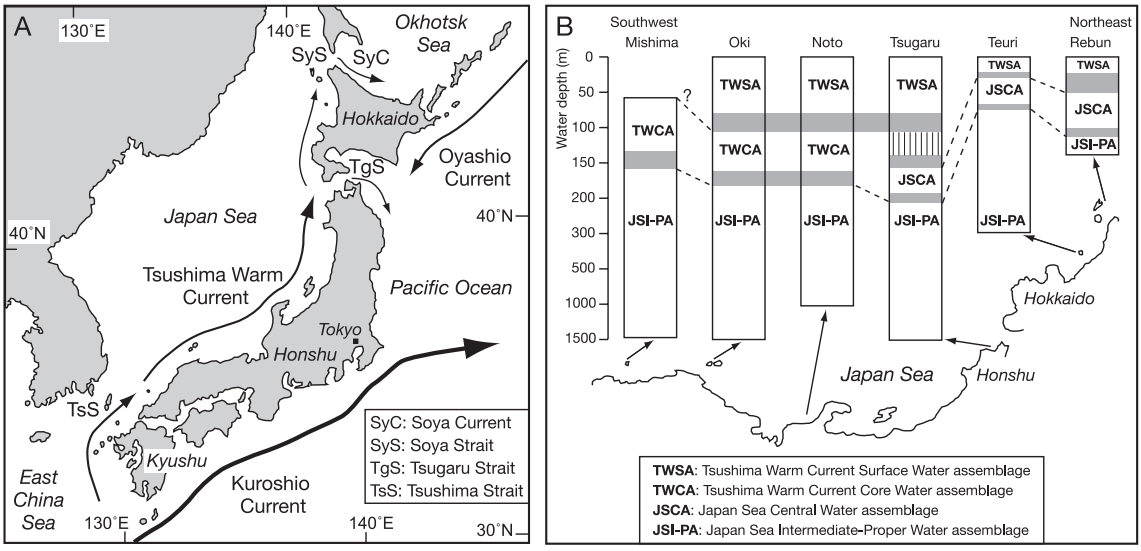

Fig. 1. (A) Map of the Japan Sea showing the locations of the three straits and the flow of the main ocean currents. (B) Water depth ranges for ostracod assemblages at six localities along the Japan Sea coast, modified after Ozawa (2003a). Vertical lines at depths of ca. 100–150 m off the Tsugaru Peninsula indicate an interval with a low occurrence of ostracods.

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