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Stable isotope of some selected Egyptian pectinids and their paleoenvironmental implications

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ABSTRACT

Eight pectinid shells were collected and subjected to quantitative study using $\delta^{18}O$ and $\delta^{13}C$ isotopic analysis in order to study the paleoenvironment which prevailed during their calcification. The scalerochronological variations in $\delta^{18}O$ and $\delta^{13}C$ values, among these shells are also discussed. The Early Miocene pectinid shells display highly depleted $\delta^{18}O$ and $\delta^{13}C$ signature as a result of paleo-meteoric water with heavy rainfall that was produced by Tropical Cyclones when the Mediterranean Sea was open. The Early Pliocene pectinid shells reveal depleted $\delta^{18}O$ values, related to the influx of fresh water influenced by monsoonal activity following the formation of the Tibetan Plateau. Their enrichment in the $\delta^{13}C$ isotopic excursion is referred to high productivity of the Indian Ocean, which was the main source of the Red Sea water. The Pleistocene pectinid shell shows highly depleted $\delta^{18}O$ and $\delta^{13}C$ signature with obvious diagenetic shell structure, indicating that a wetter humid climate prevailed during the Early–Middle Pleistocene and long sub-arial exposure of the shell. The Recent Mediterranean pectinid shell displays slight enrichment in $\delta^{18}O$ and $\delta^{13}C$ values referring to deeper inhabitation of this species with a low temperature and high salinity environment. The scalerochronological variations in both $\delta^{18}O$ and $\delta^{13}C$ values, along these shells is referred to seasonal variations or kinetic effects.

1. Introduction

1.1. Paleogeography and paleoclimatology overview

The global climate experienced a drastic transition during the Cenozoic from the warm and humid Cretaceous to the cool Quaternary with its glacial–interglacial cycles (Zachos et al., 2001). A gradual decrease in temperature during the later Eocene culminated in the formation of the first ice-sheets in Antarctica around the Eocene/Oligocene boundary, followed by global warmth at (~22–16 Ma), during the Early Miocene (Wright, 2001; Zachos et al., 2001).

During the Early Burdigalian, an extensive Indo-Pacific connection with the Mediterranean and the Paratethys took place, allowing the tropical and subtropical elements to migrate between these two provinces. In the Late Burdigalian, the counterclockwise rotation of Africa and Arabia resulted in the collision with the Anatolian plate, and the Mediterranean was cut off from the Indian Ocean forming a new landbridge (Gomphotherium Landbridge), which connected Asia and Eurasia and enabled remarkable mammalian exchange between Africa and Europe (Rögl, 1999; Harzhauser et al., 2007).

The warming trend, that continued into the Middle Miocene with a climax at the Middle Miocene Climatic Optimum (Harzhauser et al., 2007), occurred at about 15 Ma and was about 6 °C warmer than the midlatitude of the present-day (Flower and Kennett, 1994).

The climatic optimum was followed by global cooling at around 14 Ma, 'with the expansion of the East Antarctica Ice Sheet (Shackleton and Kennett, 1975; Savin et al., 1985; Miller and Katz, 1987; Miller et al., 1991; Flower and Kennett, 1994; Wright, 2001). During the Early Pliocene, the earth was significantly warmer than today. This period lasted about 5–3 Ma, with a major transition which occurred from the warm climate of the Early Pliocene to the cool, ice-age climate of the Late Pliocene and Pleistocene. The gradual cooling started at, or before, 3.5 Ma and the development of the largest Northern Hemisphere ice-sheets occurred by about 1.0 Ma (Ravelo et al., 2006).

The humid climate associated with the Early Pliocene Epoch was influenced by the Asian monsoon which was initiated 8–7 Ma in association with the uplift of Tibet (Sanyal et al., 2004). This monsoonal activity caused an intensified oxygen minimum zone and high productivity which was a result of the nutrient flux (the Indo = Pacific biogenic bloom) in the Indian Ocean waters between 5.5 and 4.0 Ma, that ended when intermediate waters cooled and become oxygenated at ~4.0 Ma (Gupta and Thomas, 1999).

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Pleistocene climates were characterized by the alternation of glacial and interglacial periods driven by the expansion and retreat of continental ice-sheets over northern latitudes (e.g. Ruddiman, 2003). It is well established that these alternations were controlled by the astronomical cycles of eccentricity, obliquity and precession (e.g. Hays et al., 1976). During the Early Pleistocene, obliquity was the dominant forcing parameter (Ruddiman, 2003). In the Middle and Late Pleistocene, the eccentricity was the dominant parameter controlling glacial–interglacial changes (Ashkenazy and Tziperman, 2004).

1.2. Stable isotope in mollusks

Previous studies indicate that different organisms, including mollusks, can provide proxy records of past and present environmental conditions, by measuring stable isotopic composition of biologically produced calcite (e.g. Grossman and Ku, 1986). It also allows quantitative information to reconstruct the environmental history of the biogenic carbonate. Mollusks can precipitate their shells in near oxygen equilibrium (e.g. Grossman and Ku, 1986) and their $\delta^{18}O$ reflects variations in the sea surface temperature (SST) and the $\delta^{18}O$ of ambient seawater from which it is precipitated (Urey, 1947; Epstein and Mayeda, 1953; Grossman and Ku, 1986). It is also related to sea surface salinity (SSS) through the process of evaporation and fresh water dilution (Latal et al., 2006b). The $\delta^{13}C$ values in the carbonate shells are mainly related to isotopic composition of dissolved inorganic carbon, but vital effects may lead to a non-equilibrium value (Latal et al., 2006a).

Pectinid are among the most frequent groups and widely distributed fossils in the shallow marine environment in the Late Cenozoic. These important groups have predominantly calcitic shells, which are highly sensitive to environmental perturbations (Harzhauser et al., 2007). Their outer shell layer is composed of pure foliated calcite, which has a high preservation potential (Mandic and Piller, 2001) and is relatively immune to dissolution and recrystallization (Chauvaud et al., 2005). Their shells can yield faithful records of their paleoenvironments (e.g. Krantz et al., 1987; Wefer and Berger, 1991; Jones and Allmon, 1995; Hickson et al., 1999). Being epifaunal, pectinid shells provide a record of ambient water temperatures rather than those of sediment-pore shells (Krantz et al., 1987). Furthermore, scallops are typically fast growing, with growth frequently continuing in the winter in younger forms, hence providing scope for fine-scale, through-year documentation of environmental change (Hickson et al., 1999).

Different studies have shown that pectinid shells have grown in various climatic settings, such as tropical and subtropical (Jones and Allmon, 1995), temperate (Krantz et al., 1987; Hickson et al., 1999) and Antarctic (Barrera et al., 1994) and precipitate their shells in equilibrium with the seawater. Moreover scallops populate only in environments with little salinity variation. Consequently, when their shells are not diagenetically altered, the variation in the $\delta^{18}O$ values of calcite can be interpreted in terms of seasonal changes in water temperatures, with lower values of calcite representing summer and higher values representing winter (Bojar et al., 2004).

In this work a quantitative study of some selected Egyptian pectinids from the Early Miocene, the Early Pliocene, the Early–Middle

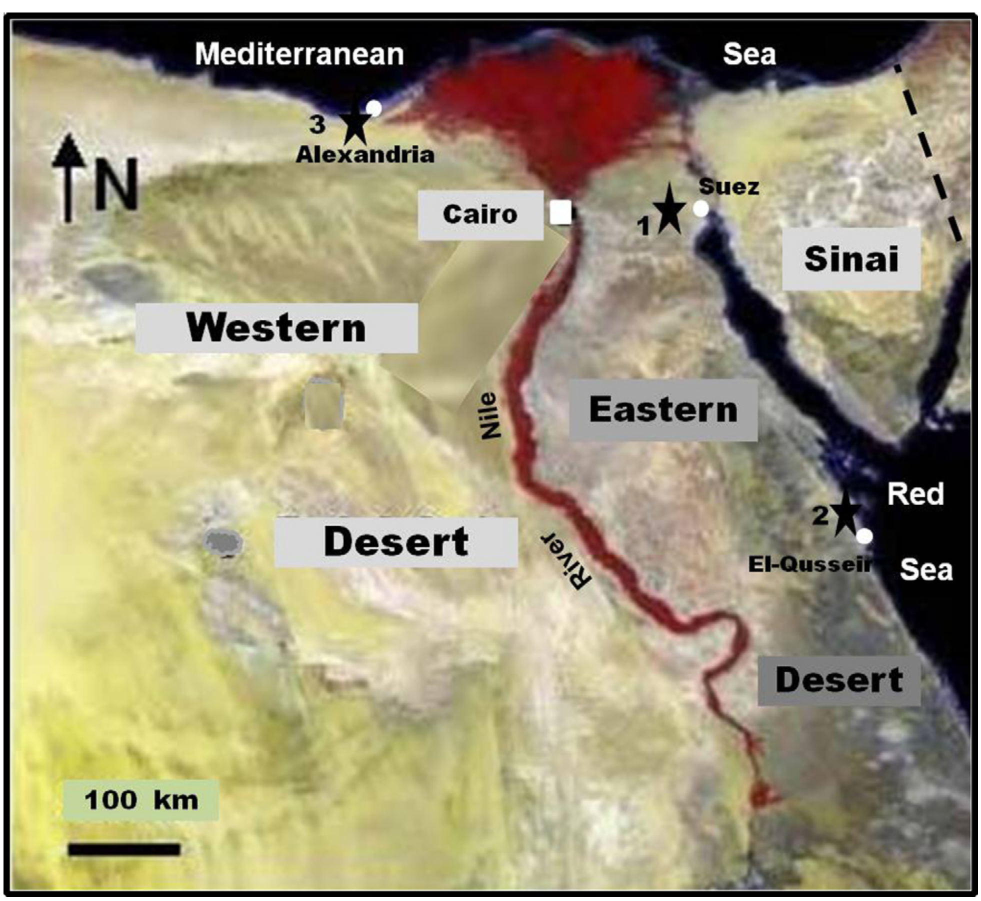

Fig. 1. Location map of the studied pectinid shells. (1) Early Miocene from the Agrud area. (2) Plio-Pleistocene from the Abu Hamra area. (3) Recent pectinid from the Mediterranean Coast west Alexandria.