Cross-Calibration of Daily Growth Increments, Stable Isotope Variation, and Temperature in the Gulf of California Bivalve Mollusk *Chione cortezi*: Implications for Paleoenvironmental Analysis

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Annual-oxygen isotope profiles from two live-collected specimens of Chione cortezi *Carpenter were analyzed in conjunction with daily growth-increment width profiles and high-resolution temperature records from the same site in the northern Gulf of California. The daily growth-increment profiles serve to date the deposition of the* $\delta^{18}O$ *samples. Then the* $\delta^{18}O$ *values were compared with high-resolution temperature records from the same site. Shell deposition began in late March or early April and ended in late November or early December.* $\delta^{18}O$*-derived estimates of the maximum and minimum temperature thresholds of growth agree well with those obtained from the dated increment width profile. Shell deposition in these two specimens of* C. cortezi *from the northern Gulf began when temperature warmed above ~17°C and slowed or halted when temperature rose above ~31°C. The temporal resolution of stable isotope samples varies throughout the year. Samples with the coarsest resolution (>3 weeks) were taken from parts of the shell deposited near the minimum and maximum temperature thresholds of growth. Higher resolution samples have intermediate* $\delta^{18}O$ *values and most represent less than five days of growth. Calculated temperatures from the dated oxygen-isotope samples are similar to observed temperatures. Differences reflect the effects of daily temperature variation, tidal emergence, and enrichment in* $\delta^{18}O$ *of the water in which the clams grew. Stable oxygen-isotope samples used in conjunction with increment-width profiles can provide paleoenvironmental information at sub-weekly to submonthly resolution.*

INTRODUCTION

The accretionary skeletons of intertidal marine bivalve mollusks contain a wealth of information about the environment in which they grew. The rate and timing of bivalve shell growth is controlled by temperature (Pannella and MacClintock, 1969; Jones et al., 1978; 1989), salinity (Koike, 1980), age and reproductive cycle (Sato, 1995), tidal cycle and intertidal position (Berry and Barker, 1975; Lutz and Rhoads, 1980; Ohno, 1989), and nutrient and food availability (Coe, 1948). These factors cause a wide variety of annual and sub-annual (seasonal, lunar, fortnightly, daily, and disturbance) growth patterns. This variation of growth patterns makes the shell a rich source of information on the environment in which it grew (Jones, 1996). It is clear that bivalve mollusk shells respond to a variety of environmental factors. Thus, calibration of environmental variation with aspects of their growth patterns is likely to yield important insight into the growth variations in fossil shells.

Although many environmental controls can affect growth, temperature is the dominant factor governing growth rates. Temperature's influence on bivalve-shell growth has been recognized for more than 60 years (see Davenport, 1938). In a later review, Gunter (1957) showed the importance of temperature to the ultimate size of marine mollusks. Berry and Barker (1975) correlated temperature with variation in seasonal growth rates, and also showed that specimens of the bivalve *Chione undatella* exhibit different growth patterns along a thermal gradient in the Gulf of California. Kennish and Olsson (1975) documented variation in daily growth-increment width as a function of seasonal temperature variation. The conclusions of these and many other observational studies have been confirmed from geochemical evidence. The development of isotope paleontology (Wefer and Berger, 1991) has given biologists and paleontologists a new tool to interpret bivalve-growth patterns. For example, Jones et al. (1983) used oxygen isotope ($\delta^{18}O$) variation to show that shell growth in the bivalve *Spisula solidissima* slows during cooler temperatures. Furthermore, they demonstrated the feasibility of reconstructing annual seasonal temperature fluctuations from stable isotopic profiles from clam shells. Annual $\delta^{18}O$ variation also has been used to reconstruct changes in seasonality in both time and space (e.g., Jones and Allmon, 1995; Khim et al., 2000).

Here climatic, isotopic, and sclerochronologic records from the northern Gulf of California are discussed (Fig. 1). The main goals in this study are: (1) to describe the annual pattern of shell growth in a bivalve species from the northern Gulf; (2) understand the relationship between temperature and shell growth; and (3) interpret annual oxygen-isotope profiles as potential sources of paleoclimatic information. Using daily growth increments from specimens of the intertidal bivalve *Chione cortezi* Carpenter, annual isotopic profiles have been calibrated with high-resolution temperature observations. This calibration has allowed the determination of the timing and rate of shell growth throughout the year. This high-resolution calibration should prove useful in interpreting isotopic and sclerochronologic variation in fossil shells of this and other species.

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