Environmental Significance of Oxygen Isotopes in the Bivalve Protothaca grata *from Archaeological Sites in Northeast Baja California*

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Abstract

Oxygen isotopes in mollusk shells are a very useful tool in archaeology for reconstructing environmental conditions during human occupation of coastal areas. Shells from archaeological middens have been used mostly to provide information about the season of mollusk harvest, ambient temperature and its variability, as well as the characteristics of the water where the organisms lived. With regard to the latter, human settlement in the Mexicali Valley and adjacent areas has been dependent since prehistoric times on the Colorado River's flow. In order to evaluate the influence of river water in coastal cultural settings, we explored the possibility that isotopic signals could provide that information. We used isotopic analyses and radiocarbon dates obtained from *Protothaca grata* (littleneck clam) shells coming from a now-destroyed midden in San Felipe, and from a second midden at Campo Cristina, south of San Felipe, in Baja California, where no influence of fresh water is expected. Isotopic data suggests that between 1220 and 1065±50 BP, there was influence from the river's fresh water as far south as San Felipe, but not at Campo Cristina, which was contemporaneous with San Felipe and dated to 1269±45 BP. This study shows that oxygen isotopes could be a useful tool to reconstruct the environmental characteristics in arid cultural settings.

Introduction

The most common archaeological features on the coasts of the Baja California peninsula are shell middens, characterized by dense accumulations of discarded mollusk shells in coastal areas and sometimes inland as well. Despite their abundance, little is known about the cultural significance of these middens. Among the varied information that can be gained from mollusk shells are data on the ecological contexts within which the native peoples lived, complementing that obtained from the associated artifacts. Mollusk shells attest to the marine environment from which they came, inferred from the organisms' habitat preferences. The shells' isotopic composition is a very useful archaeological tool for reconstructing the variation in environmental conditions that prevailed during human occupation of the coastal areas, as well as seasonality in mollusk collecting, water temperature and its variability, and the admixture of fresh water from the continent (Flessa et al. 1997).

Since prehistoric times, human settlement in the Mexicali valley and adjacent areas has been dependent upon the Colorado River's flow. In turn, the influence of the river in its delta has been very important—throughout the area reached

by its diluted waters—in modeling the presence and abundance of mollusks, some of which, such as the bivalves *Chione* spp. and *Protothaca* spp., were used for food by the native groups in coastal areas. This article presents some results of isotopic analyses and radiocarbon dating of *Protothaca grata* (multicolored clam) shells from two sites: the first a now-destroyed midden located at the town of San Felipe, and a second midden located approximately 65 kilometers (41 miles) farther south at Campo Cristina, with the aim of determining whether isotopic variation reflects the influence of the Colorado River's waters. The use of the isotopic method archaeologically for reconstructing fresh-water influenced paleoenvironments is also briefly discussed.

Theoretical Basis for the Interpretation of Oxygen Isotopes

Seawater contains two main oxygen isotopes, ^{18}O and ^{16}O. These vary in abundance within seawater as a function of temperature: at higher temperatures, seawater that is isotopically light (molecules with ^{16}O) is evaporated preferentially, enriching the residual water with the heavier isotope (^{18}O). Thus the ratio $^{18}O/^{16}O$ is used as an index, expressed as $\delta^{18}O$ (or the change in the proportion of ^{18}O from the standard), which varies proportionally to temperature with respect to an equilibrium of zero parts per million (ppm). Since mollusks build their calcium carbonate shells by taking oxygen from the surrounding water, the shell has an isotopic composition that reflects the water in which it lives. When this oxygen isotope ratio changes as a function of temperature this variation in the seawater is recorded in the shell's growing lines.

One exception to this rule occurs when there is an input of fresh water from discharging rivers. The isotopic composition of water with a fluvial origin is lighter than that of seawater, because the water has passed through several cycles of evaporation, condensation, and precipitation. This means that at higher latitudes, the water is isotopically lighter. For this reason, water from the Colorado River is isotopically lighter than the seawater into which it is discharged, and mollusk shells therefore ought to contain an isotopic signal in addition to the one from temperature. Figure 1 shows how the isotopic

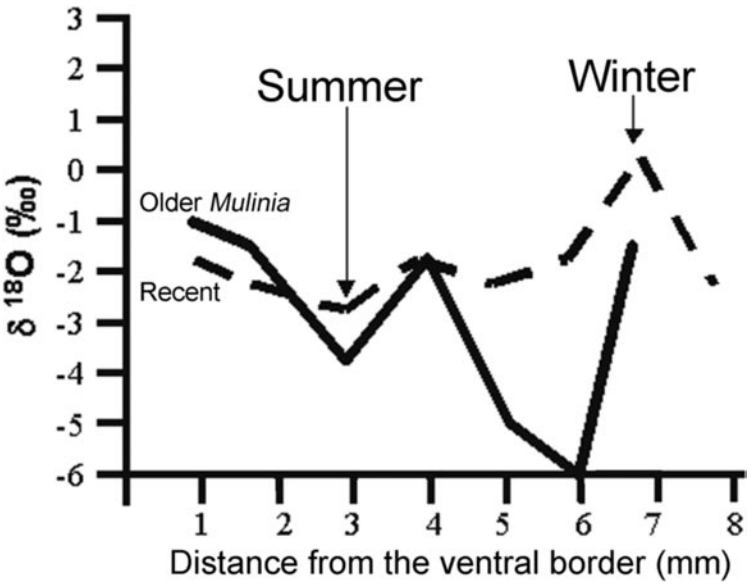


Fig. 1. Variation in the isotopic composition of a recent specimen of Chione fluctifraga*, under conditions in which fresh water was absent, and* Mulinia coloradoensis*, prior to the control of the Colorado River's waters. Data after Rodríguez et al. 2001.*

composition of a *Chione* sp. shell varies during the annual cycle in the Colorado delta, subsequent to the elimination of the input of fresh water. Note that the values are no lower than -3 ppm (actually -2.48 ppm; Rodríguez et al. 2001), with the isotopic variation in this case being due exclusively to temperature changes. This contrasts with values of around -6 ppm obtained from a *Mulinia coloradoensis* shell from older deposits located in the same area, created when, in the absence of dams, the Colorado River flowed freely as far as the delta (Fig. 1). The foregoing discussion suggests that values above -2.5 ppm are due to temperature variation, and that lower values are attributable to the presence of isotopically lighter fresh water.

Study Area and Methods

Two *Protothaca grata* shells collected from the surface in the remains of the shell midden in San Felipe, plus one shell of the same species from Campo Cristina, were analyzed in this study (Fig. 2). *Protothaca grata* shells from both sites were radiocarbon dated, and a piece of charcoal from the San Felipe site was also dated. On the shells (Fig. 3), samples were taken along the growth lines from the umbo to the ventral border, and their isotopic compositions were analyzed at the University of Arizona's Isotope Geochemistry Laboratory in Tucson.

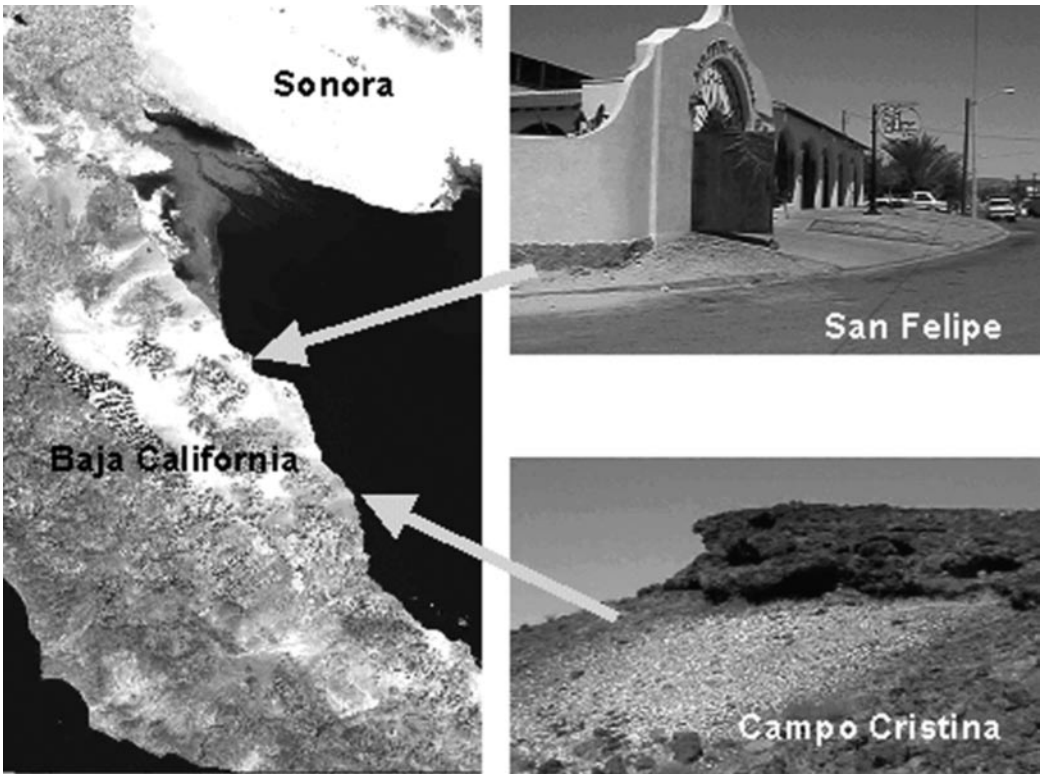


Fig. 2. Study area. Only fragments of the San Felipe shell midden remain in the building's foundations. The Campo Cristina midden is still almost intact.

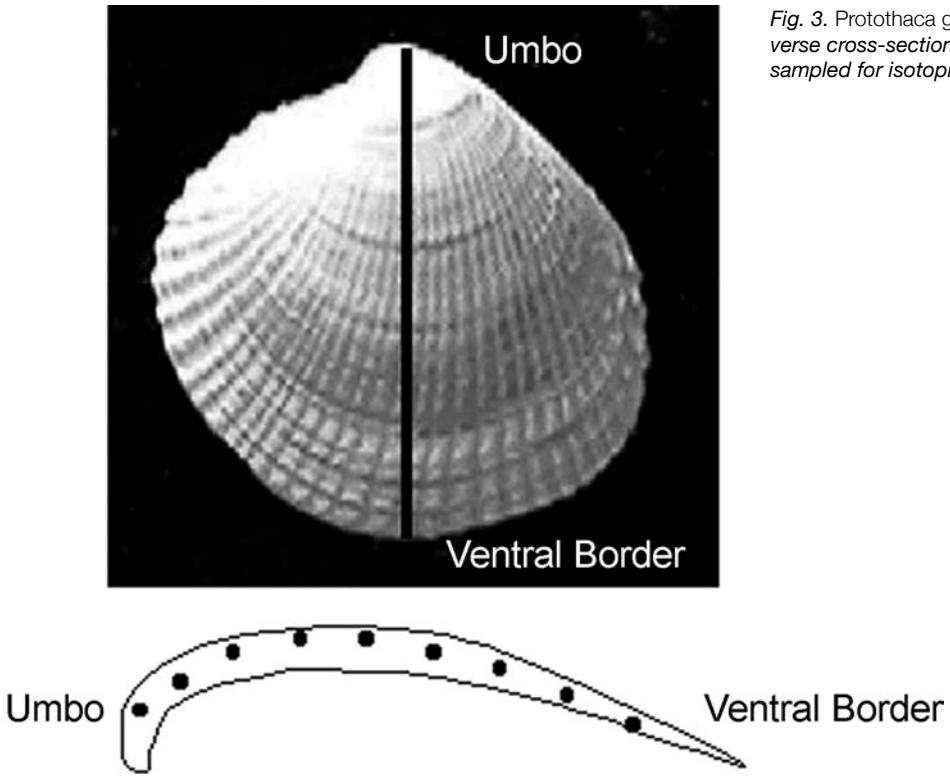
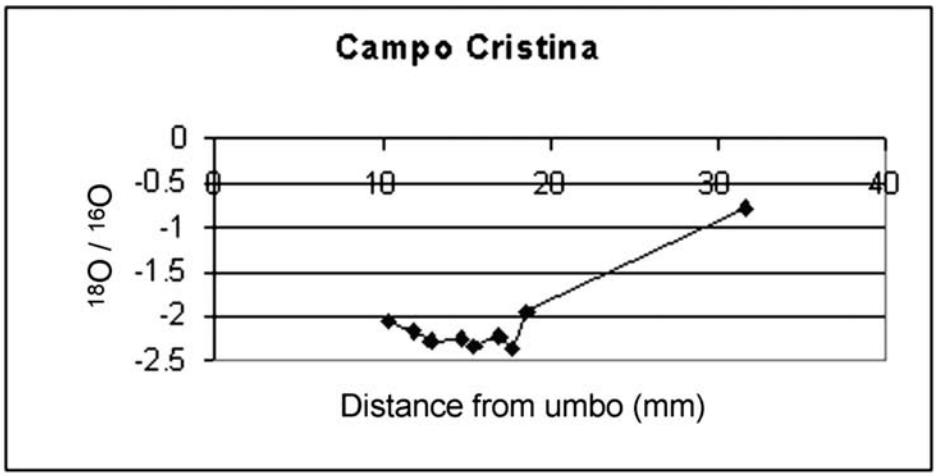


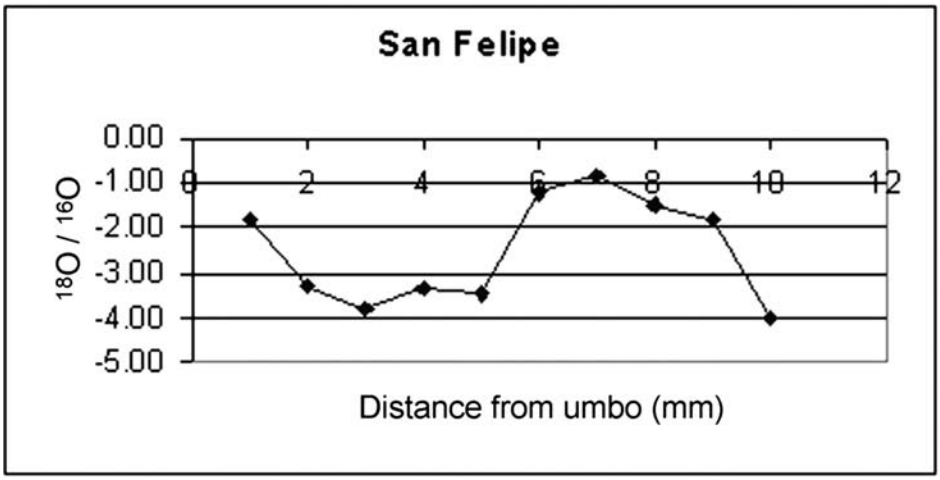
Fig. 3. Protothaca grata *shell and a transverse cross-section showing how the shell is sampled for isotopic analysis.*

Results and Discussion

The shell and charcoal from the midden at San Felipe were radiocarbon dated to 1025±90 BP and 1220±50 BP respectively. The shell from Campo Cristina yielded a comparable date of 1269±45 BP. Because the analytical error ranges overlap in the case of the San Felipe charcoal and the Campo Cristina shell, and these in turn are sufficiently close to the San Felipe shell date, both archaeological sites appear to have been occupied during the same period. For the San Felipe midden, isotopic analysis of the two shells shows the typical variation expected for temperature change during a yearly cycle (Fig. 4b, 4c). However, minimum values between -3.44 and -3.99 ppm were found, suggesting the influence of fresh water from the Colorado River. In the case of the midden at Campo Cristina, the minimum value was -2.37 ppm (Fig. 4a), suggesting that there was no influence from fresh water and that the isotopic variation was due exclusively to temperature. Although there have been no previous studies of the effects of oxygen fixation in the calcium carbonate in *P. grata* shell, taking as a model the isotopic variation in *Chione* sp. and *Mulinia coloradoensis* under the influence of temperature and the influx of Colorado River water, the result is very similar to that reported by Rodríguez et al. (2001). However, given the limited data available, further research is needed at more archaeological sites inland and along the coast to support our data.

Based on the preceding discussion, and given the abundance of shell middens both on the Pacific coast and on the Gulf of California coast, isotopic





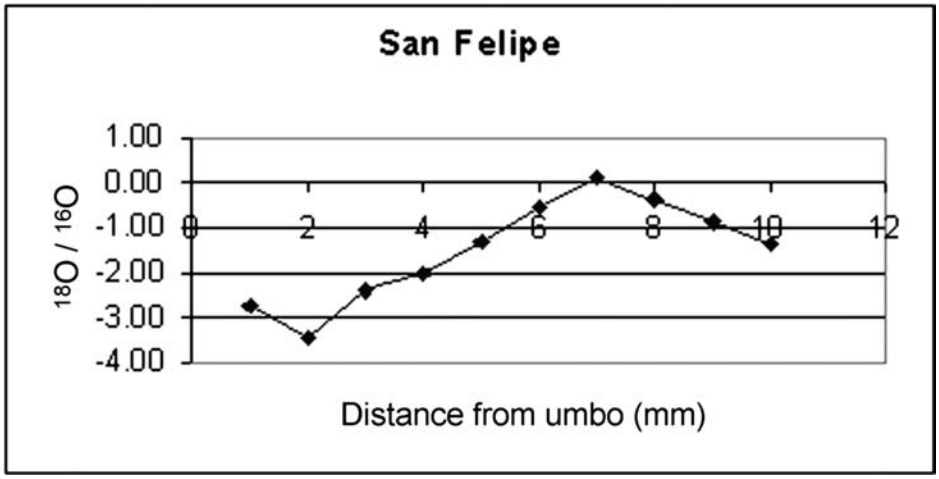


Fig. 4. Isotopic analysis of Protothaca grata *shells from Campo Cristina (a) and San Felipe (b, c). Greater negative values in the San Felipe specimens suggest the influence of fresh water.*

analysis of mollusk shells offers another tool for determining environmental gradients and variations, as well as the season of mollusk harvesting (Killingley 1981). The latter could not be addressed in the present study because of the small sample size.

In Mexicali Valley, there are numerous archaeological remains in the area of Mesa de Andrade, located on what was the old shoreline of Lake Cahuilla (Fig. 5). Although the inland area of prehistoric Lake Cahuilla lacks the large, extensive shell middens commonly found along the coast, the inland sites do contain many shell fragments (Fig. 6), and these potentially may provide information about collecting locations and their proximity to the Colorado River on the basis of isotopic signatures. At these inland archaeological sites, pottery is abundant (Fig. 7); in contrast, no surface evidence of ceramics was seen at San Felipe or Campo Cristina, which seems to suggest that the sites belonged to different aboriginal groups. What work has been done identifies the need for conducting additional investigations of desert cultures, primarily in those areas where a serious threat has arisen first of all from urban growth, as in the case of Mexicali and its valley, as well as from the proliferation of off-road vehicles with unrestricted access to desert areas where archaeological remains are located.

Fig. 5. Margin of ancient Lake Cahuilla on Mesa de Andrade. Archaeological remains are common on the sandy surface of the mesa.

Fig. 6. The arrow points to a piece of mollusk shell on the surface of Mesa de Andrade, along the margin of ancient Lake Cahuilla.

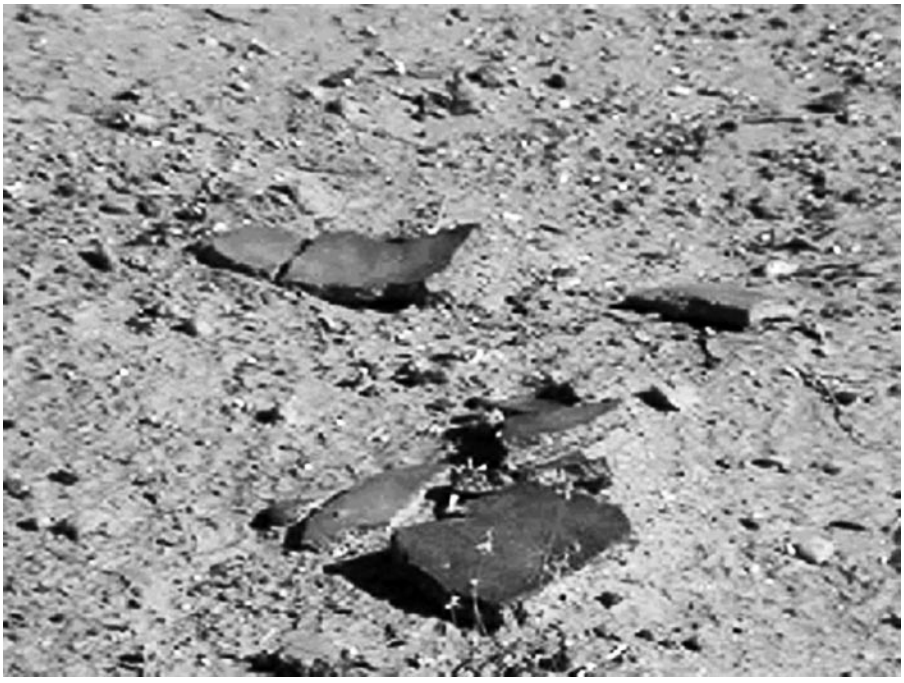


Fig. 7. Pieces of pottery are common on the sandy surface of Mesa Andrade, along the margin of ancient Lake Cahuilla.

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References Cited

Flessa, K. W., D. Surge, D. L. Dettman, M. A. Téllez Duarte, G. A. Goodfriend, and J. C. Zachos
1997 Los isótopos de oxígeno en bivalvos marinos pueden ser utilizados para estimar la afluencia de agua del río Colorado en su delta (abstract). In, *Memorias de la IV Reunión sobre Geología de la Península de Baja California*. Sociedad Geológica Peninsular, Universidad Autónoma de Baja California.

Killingley, J. S.
1981 Seasonality of Mollusk Collecting Determined from O-18 Profiles of Midden Shells. *American Antiquity* 46:152-158.

Rodríguez, C., K. Flessa, M. Téllez, D. Dettman, and G. Avila
2001 Macrofaunal and Isotopic Estimates of the Former Extent of the Colorado River Estuary, Upper Gulf of California, Mexico. *Journal of Arid Environments* 49:183-193.