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Isotopic Evidence of Sources for Central California *Olivella* Beads

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ABSTRACT

Without the large bead production sites present on the Channel Islands, the origin of *Olivella* beads in central California has been largely speculative. Stable isotope analysis of shell carbonate provides a useful test of source, production, and distribution hypotheses by providing information about the environment of shell formation. We reassess results of previous stable isotope sourcing studies and employ a cluster analysis that suggests most *Olivella* beads recovered from central California were produced from shell harvested from the Central Coast or Bay Area, but conveyance from southern California also contributed to the bead supply by the end of Phase 1 of the Middle Period (ca. 1,545 BP). Bead production in central California appears decentralized relative to large Channel Island workshops, a difference that likely reinforced the divergent sociopolitical trajectories of the regions.

RESUMEN

Sin los grandes sitios de producción de las cuentas en las Islas de Canal, el origen de las cuentas *Olivellas* en el centro de California ha sido principalmente especulativo. El análisis de isótopos estables de carbonato de conchas marinas produce una prueba de las hipótesis de origen, producción, y distribución al proveer información sobre el entorno de formación de la valva. Reevaluamos estudios de fuentes de isótopos estables y usamos un análisis de conglomerados que sugiere que la mayoría de las valvas Olivella recuperadas en el centro de California se produjeron a partir de cuentas recolectadas en la costa central o en el área bahía. El comercio desde el sur de California también contribuyó al suministro de valvas al final de la Fase 1 del Período Medio (ca. 1,545 AP). Producción de cuentas en el centro de California parece descentralizada en relación con talleres de las Islas de Canal, una diferencia que probablemente reforzada por las trayectorias sociopolíticas divergentes de las regiones.

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Olivella[1] beads are a common artifact from archaeological sites in Alta California. The earliest beads are simple spire-removed examples from interior and coastal sites dating more than 10,000 years old (cal BP; Basgall and Hall 1993; Erlandson et al. 2005; Fitzgerald, Jones, and Schroth 2005; Hadden et al. 2017). Various styles of *Olivella* beads were manufactured through the middle and late Holocene, continuing into the Mission and American periods (Bennyhoff and Hughes 1987). At the time of contact, *Olivella* beads were used by Native Californians in a range of ways, including as personal adornment, decoration on clothing and basketry, and especially as items of trade and markers of wealth (Gifford 1947; King 1990).

Early archaeological studies used morphology and size to develop *Olivella* bead typologies (Bennyhoff and Fredrickson 1967; Bennyhoff and Heizer 1958; Gifford 1947; Lillard, Heizer, and Fenenga 1939). The resulting typologies were then used to cross-date sites among regions of California (Gifford 1947). As absolute dates began to be assigned to *Olivella* beads, it become clear that, with a few important exceptions, morphological types share similar chronological ranges in central and southern California, indicating that beads were likely exchanged between the regions (Bennyhoff and Hughes 1987; King 1990). Studies of exchange focused on the appearance of California bead types in Great Basin contexts, where local shell collection could be ruled out, found that types most common in both southern and central California were traded into the Great Basin (Bennyhoff and Heizer 1958; Bennyhoff and Hughes 1987). These studies assumed that bead types were primarily produced in the region where they occur in the greatest abundance. For example, Middle Period (ca. 2,150-930 BP) Class F "saddle" and Late Period (ca. 685–180 BP) Class M "thin rectangle" *Olivella* beads are abundant in central California, but are generally absent from southern California, and thus are assumed to be produced in the former area.

This assumption is seemingly at odds with direct archaeological evidence for bead production. Sites on southern California's Channel Islands exhibit abundant shell detritus, incomplete beads, and drills in quantities that suggest continuous and centralized large-scale production for centuries (Arnold 1987; Arnold and Graesch 2001). Production at a similar scale has never been found north of Point Conception. Dozens of central California sites have small numbers of *Olivella* fragments and bead blanks suggesting widespread, low-intensity bead production (Burns 2019; Rosenthal 2011). Well-documented evidence for more intensive production only exists in two locations: CA-NAP-539 where the entire Class

M bead production sequence is present (Hartzell 1991) and CA-SMA-18 and CA-SMA-19 at Año Nuevo where shell was collected, heat treated, and fractured (Hylkema and Cuthrell 2013), with neither location exhibiting bead production on the scale observed at Channel Island sites, or in sufficient numbers to account for the millions of beads found in central California burial and midden contexts.

While the role of beads in California culture changed through time, their consistent role as an accompaniment to burials highlights a continuity in high cultural significance (Bettinger 2015; Burns 2019; Gamble 2020; King 1990). The possibility that southern California groups dominated bead production and distribution has been offered as a significant contributing factor for emergent political complexity (e.g., Arnold and Munns 1994; Gamble 2011). As such, the extent to which bead production was concentrated at single sources, in southern California or elsewhere, has broader implications for the understanding of California sociopolitical organization.

Confirmation of production and distribution patterns depends on sourcing of beads. In southern California and the Southwest, some beads made from large portions of shell can be sourced to broad areas based on the modern geographic distribution of identified species (e.g., *O. dama*). This approach assumes that species did not shift in their distribution over time, for example, with global climatic shifts (e.g., Beaugrand et al. 2002; Dambach and Rödder 2011). Unfortunately, most *Olivella* bead types in California are made from a small portion of the outer shell wall. Due to the limited geographic variability and lack of distinguishing features present on most finished beads, morphological variation in *Olivella* shells has not proven to be a useful approach for sourcing of wall beads in most of California (Gifford and Gifford 1944; Mitchell 1992; Stohler 1959).

Stable isotope analysis has emerged as an alternative method for sourcing shell artifacts based on the growing conditions of the water where an organism developed. Carbon and oxygen isotopes incorporated into shell carbonate are dependent on water temperature and local isotopic content of seawater as determined by major currents, upwelling, evaporation, and freshwater input (Bean, Hill, and Guerra 2007; Eerkens et al. 2005; Killingley and Berger 1979; Mook and Vogel 1968; Urey 1947). Initial studies attempted to source *Olivella* beads by developing isotopic signatures using modern shell collected from known locations on the California coast (Eerkens et al. 2005). This technique has been successfully applied for discriminating shell from highly variable environments such as the Pacific Coast and Gulf of California (Grimstead et al. 2013). While this approach offers the potential for the most precise geographic matching, differences in isotopic values between ancient and modern specimens indicate that this line of inquiry is unlikely to prove successful for resolving sources on the California coast.

The Suess effect (reduced $^{13}CO_2$ concentration) and increases in sea surface temperature are both global-scale phenomena associated with the introduction of carbon from fossil fuel sources that contribute to this difference (Bacastow et al. 1996; Callendar 1938; Eide et al. 2017a, 2017b; Keeling 1979; Suess 1955). These environmental perturbations should result in systematic isotopic changes that can be accounted for in *Olivella* geochemistry. In practice, local changes in ocean currents associated with both recent and long-term changing climate throughout the Holocene are larger than the global-scale phenomena (e.g., Dyez et al. 2007; Dyez et al. in press; see Hutchinson [2020] regarding similar challenges associated with ΔR estimates for ^{14}C age calculations). These changes are harder to predict or measure, making selection of an appropriate correction for unsourced shell challenging.

The consequence of these changes between ancient and modern isotopic environments is demonstrated in Eerkens et al. (2007). Based on modern isotopic ranges, that study assigned 17 of 29 beads of types only found in central California to the southern California shell source. Eleven of the remaining beads had ambiguous values between modern northern and southern coastal sources (Eerkens et al. 2007, 186). Figure 1 plots the isotopic values of beads incorporated in Eerkens et al. (2007). It is striking that although both southern and central California bead types fall within the isotopic range of modern southern California shell, there is no overlap in the isotopic space occupied by the two bead populations.

Ancient bead production sites offer the potential to be used independently to determine source isotopic ranges. This is a particularly fruitful approach in southern California, where deposits contain extensive bead production materials spanning much of the Middle and Late periods with good stratigraphic integrity. Most of this production occurred on island sites with suitable beaches for collecting *Olivella* where the likelihood that raw shell was imported from distant locations is negligible. Although relatively few beads of expected southern California types have been analyzed, those that have correspond well with material sampled from production sites, suggesting a consistent isotopic range for southern California sources (Eerkens et al. 2010).

Production sites are rare in central California and the Central Coast, making characterization of source isotopic ranges challenging. The best example of bead production in central California is at CA-NAP-539, but the site is far from coastal shell sources and *Olivella* bead production was limited to the Late Period (Hartzell 1991). Large deposits of *Olivella* shell fragments at Año Nuevo Beach are the best example of a significant production site on the Central Coast (Hylkema 1991; Hylkema and Cuthrell 2013). Since sites are immediately adjacent to sandy beaches where *Olivella* can be collected, the deposits likely represent a local source.

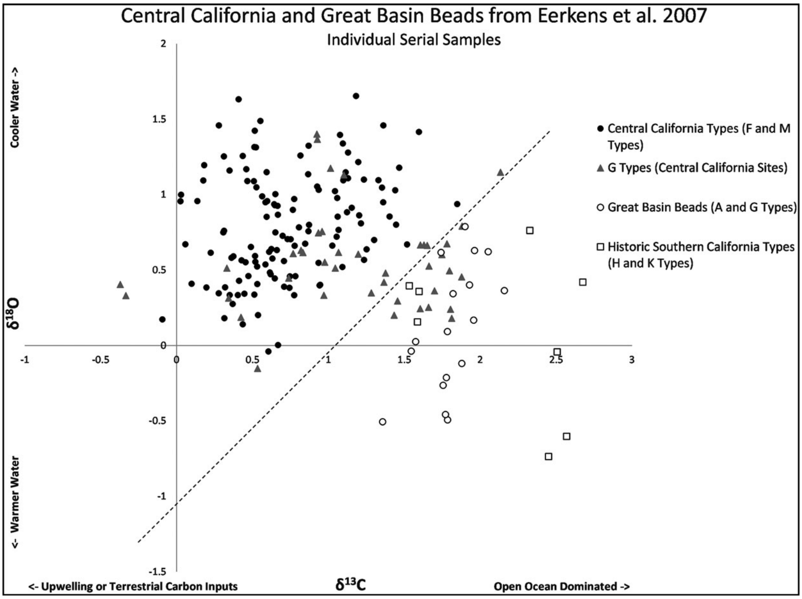

Figure 1. Isotopic values for serial samples from beads originally presented in Eerkens et al. (2007). Dashed line indicates empirical division, with all beads of suspected central California types (F and M) to upper left, and beads associated with the southern network to lower left. Three beads with a highly depleted estuarine source signal are outside the plotted region.

However, stable isotope analysis of *Olivella* and other shell from the area indicates that local isotopic values fluctuated significantly through time (Burns 2019; Dyez et al. 2007; Dyez et al. in press). To the limited extent that prehistoric shell sources have been identified along the central California coast, their isotopic values occur as a subset within the range indicated by the central California beads. This lends credibility to the observed division between southern and central isotopic ranges for known bead types, but also suggests that the sources of most central California beads have not been detected in the archaeological record.

Since the origin of central California *Olivella* beads is of primary importance to understanding the development of trade networks and the origins of political complexity, this study reconsiders the sources for these beads. We first demonstrate that modern shell should not be used to develop isotopic source estimates for ancient shell, and that doing so has biased previous studies toward attribution to a southern source. We then employ an empirical cluster analysis to demonstrate support for local production of unique regional bead types. Extension of this clustering to other bead types supports both local bead manufacture in central California and long-distance conveyance from southern California as enduring activities.

Materials

A total of 397 archaeological specimens from throughout California were sampled for this project, including beads, bead production debris, and whole shell of known coastal sources to determine source isotopic ranges. This study evaluates the source for 189 wall beads[2] within that sample recovered from central California, including the counties of Alameda, Colusa, Contra Costa, Napa, San Francisco, San Joaquin, Santa Clara, and Yolo. The sample includes 34 distinct types and subtypes covering the majority of *Olivella* bead varieties used in central California from the Early (ca. 5,500–2,550 BP) to Late periods. Class H beads are excluded from the analysis, as the distribution of these beads is known to be related to the Mission system (e.g., Gibson 1976; Sandos 1991), and analysis of their isotopic sourcing is considered elsewhere (Burns 2019; Eerkens et al. 2005; Hylkema and Maher, in preparation).

On the other hand, Class E beads with continuity in use between the Late and Mission (180–115 BP) periods are included here, as their distribution is less clearly a function of Spanish missionary interference. Sample size within types varies according to availability for destructive analysis, with some types represented by a single example, while others have samples more conducive to determining source variability within type (see Table 1). Most bead types are sampled from multiple sites (see Burns 2019). Analysis of the difference between ancient and modern shell is based on whole shells collected from coastal archaeological sites and 12 modern shells (152 serial samples) previously presented by Eerkens et al. (2005) from paired locations.

Methods

Stable Isotopes

Stable isotope sampling of *Olivella* beads in this study followed the procedures outlined by Eerkens et al. (2005), as revised by Burns (2019). Beads were first cleaned by sonication in de-ionized water. Sonication was repeated with fresh water until the fluid remained visually clear and devoid of contaminants. Beads were then dried under flowing room temperature air for a minimum of 24 h. Any visible material adhering to shell after the sonication procedure was manually removed with a scalpel, and the shell was cleaned again through sonication.

After cleaning, samples were removed from the bead with a Foredom rotary tool equipped with a 0.3 mm round bur. Samples were taken in a series of linear bands parallel to the growth lines of the shell (Figure 2). Samples were drilled to a depth no greater than 0.25 mm. Spacing between samples varied depending on the size and stability of the bead.

Table 1. Bead Types Sampled with Expected and Isotopically Determined Sources.

Type	*n*	Expected[a]	Southern	Central	Indet.[b]	Isotopic source
B1	4	Central		4		Central
B2	2	Central		2		Central
C2	3	Uncertain		3		Central
C3	5	Uncertain	1	3	1	Central and Southern
C7	1	Central		1		Central
C8	1	Central		1		Central
C10	1	No prediction			1	Indeterminate
D1a	4	San Joaquin Valley	4			Southern
D2	1	Central	1			Southern
E1b	5	Central and Southern		4	1	Central
E2a	9	Central	1	3	5	Central and Southern
E2b	1	Central and Southern			1	Indeterminate
E3a	2	Central			2	Indeterminate
E3b	3	Central			3	Indeterminate
F1	1	Central		1		Central
F2a	6	Central		6		Central
F2b	5	Central		5		Central
F2c	2	North-Central		2		Central
F3a	27	Central	1[c]	25	1	Central (and Southern?)
F3b	18	Central	1	16	1	Central and Southern
F4a	3	Central		3		Central
F4b	2	Central		2		Central
F4c	4	North-Central		1	3	Central
F4d	4	North-Central		2	2	Central
G1	4	Central and Southern		1	3	Central and Southern
G2a	11	Central and Southern	2	5	4	Central and Southern
G2b	11	Central and Southern	2	5	4	Central and Southern
G3a	1	Central		1		Central
G3b	5	Central		5		Central
G4	1	Southern		1		Central
G5/G6	4	Central and Monterey	1[c]	2	1	Central (and Southern?)
L[d]	9	Central and Southern		8	1	Central
M1a	15	Central		15		Central
M2a	14	Central		14		Central
		Totals	14	141	34	

[a]Per Bennyhoff and Hughes (1987).
[b]Indet. = indeterminate.
[c]Possibly mistyped G2 outlier.
[d]Subtypes recognized but grouped for this study.

For small beads, tight spacing was employed to maximize data acquisition. A minimum spacing of 0.5 mm was maintained from center to center between samples. Larger beads and whole shells were sampled with slightly wider spacing. A maximum sample spacing of approximately 1 mm from center to center was used. Samples included in this study that were taken during method development used a 0.5 mm bur, and employed a spacing between 0.5 and 2.5 mm between samples (Eerkens et al. 2005).

Samples were processed in the UC Davis Stable Isotope Laboratory on a GV Instruments Optima isotope ratio mass spectrometer (IRMS). Between 50 and 100 µg of powdered sample was weighed out into copper reaction

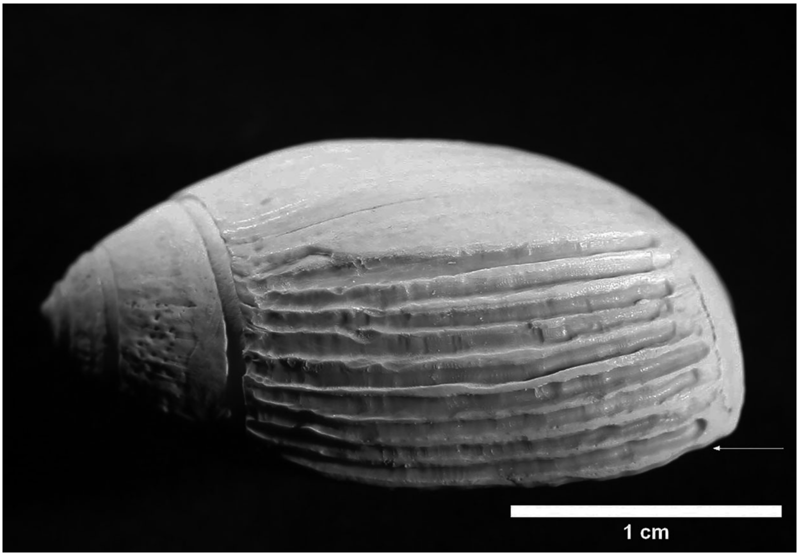

Figure 2. Whole shell from CA-SMA-18 after drilling 10 closely spaced serial samples. Arrow indicates first sample, taken at terminal growth edge.

boats, then heated to 75°C under vacuum for 30 min to drive off absorbed water and volatile organics. Samples were then loaded into an ISOCARB automated common acid bath system and reacted with 105% phosphoric acid at 90°C. Carbon dioxide released by the reaction was purified through a series of cryotraps and introduced from the final liquid nitrogen cold finger to the IRMS through a dual inlet system.

Measured stable isotope ratios are reported in delta notation with respect to the Vienna Pee Dee Belemnite international standard. Precision of $\delta^{18}O$ and $\delta^{13}C$ values is ±0.09 and ±0.07‰, or better, based on interspersed analysis of the in-house standard, while machine calibration is maintained with the NBS-19 standard.

Analysis

Comparison between modern and ancient shell isotopic ranges was conducted in version 4.0.5 of the R statistical environment using the MANOVA.RM package to conduct repeated measure MANOVA analysis (Friedrich, Konietschke, and Pauly 2019; R Core Team 2021). To conform to the requirements of the statistical test, isotopic results were re-sampled into series of eight consecutive serial samples from each shell.

This serial sampling technique generates a range of isotopic values for each bead that makes sourcing analysis through typical clustering techniques difficult. This study employs the observed isotopic separation

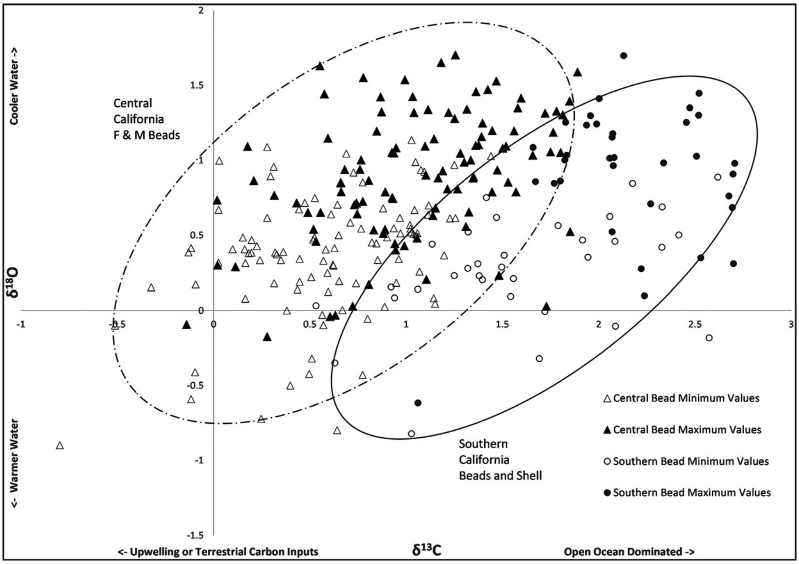

Figure 3. Isotopic values of beads used in the training set for central California (triangles) and southern California (circles). For clarity, total isotopic range of serial samples from each bead is summarized by maximum (solid) and minimum (open) values. Ellipses represent estimated source range variability used in subsequent source assignments.

between beads and shell of known southern California origin and Class F and M beads of presumed central California origin to estimate the source of unknown beads (Figure 3). Beads with some or all isotopic serial samples in the isotopic range exclusive to central California beads are classified as deriving from a central California source. Beads with some or all isotopic serial samples in the isotopic range exclusive to southern California beads are classified as deriving from a southern California source. Beads with minimum and maximum isotopic values that fall within the range of overlap between southern and central sources are considered indeterminate. Beads unusually depleted in both ^{13}C and ^{18}O originate from estuarine environments which are largely absent from southern California in the Holocene, and are classified as central California sourced shell (Eerkens et al. 2009).

Although Class F and M beads were used to generate expectations for the central California isotopic range, individual beads in these classes were subject to the same classification procedure to determine if beads from any types in these classes may be unanticipated imports. Since the principal objective of this study is to assess the importance of long-distance conveyance from major production centers on the Channel Islands, isotopic ranges associated with the entire Central Coast between Point Conception and

San Francisco Bay are lumped together as a single central California source, even though much of this region would not have been geographically or culturally "local" to other parts of the central California study area.

Results

Comparison of Modern and Ancient Shell

The incompatibility between modern and ancient shell source samples for a portion of the California coast that has been well sampled both for modern and ancient shell at apparent bead production sites near a shell source is displayed in Figure 4. Serial samples of whole *Olivella* shells from coastal archaeological sites on the Central Coast south of San Francisco Bay and north of Santa Barbara are plotted. Ellipses represent isotopic ranges from portions of the California coast estimated from modern *Olivella* samples by Eerkens et al. (2005). If modern samples were a good indicator of long-term isotopic ranges, the majority of ancient samples would fall within the dashed ellipses, and outliers would be randomly distributed. Instead, nearly a third of ancient shells have lower $\delta^{18}O$ values that would be unambiguously southern in origin based on modern references.

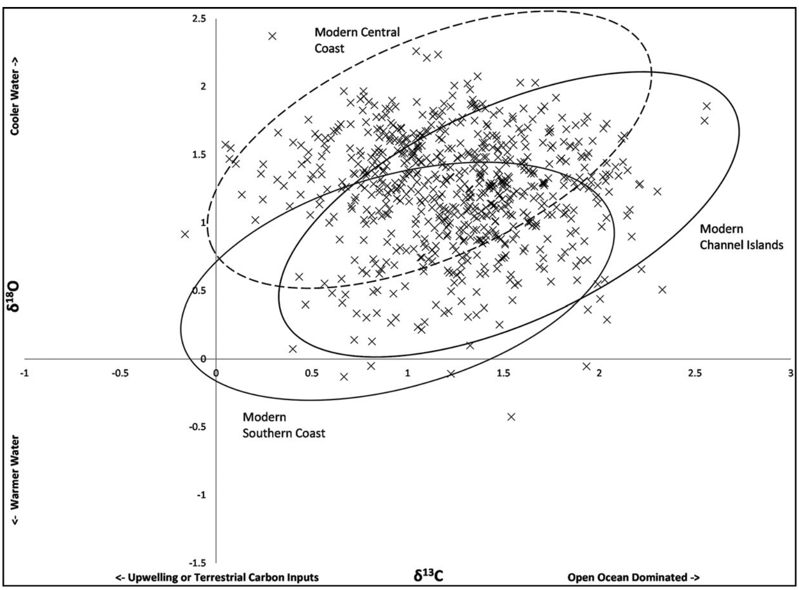

Figure 4. Comparison between isotopic ranges defined by modern shell samples from the Central Coast (dashed), Channel Islands (solid black), and Southern Coast (solid gray) in Eerkens et al. (2005) (ellipses, individual samples not plotted), and serial samples from ancient shell at Central Coast archaeological sites.

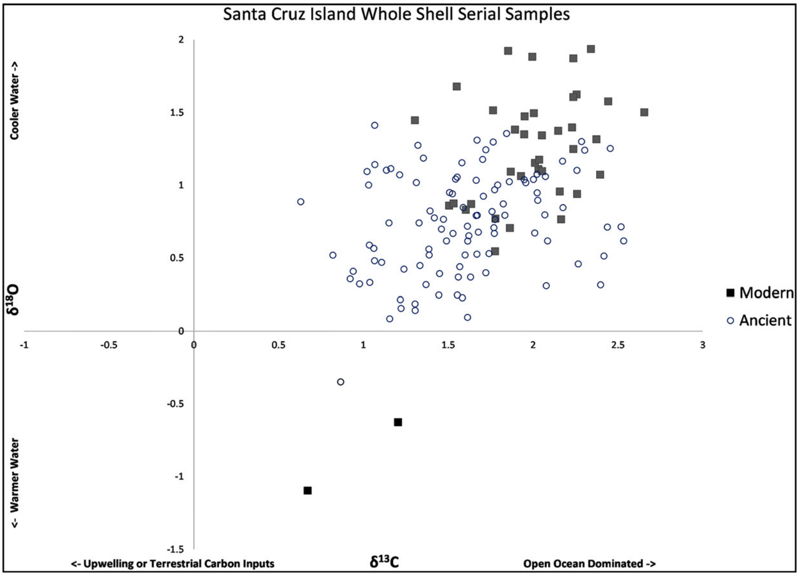

Figure 5. Comparison between isotopic values of serial samples from ancient and modern whole shells on Santa Cruz Island.

Statistical analysis shows that modern and ancient samples are from different isotopic distributions (Repeated measure MANOVA, MATS = 58.1, $p = 0.023$). Exposure to heat during cultural practices of heat treating for production or fire exposure in funerary contexts could result in reduced $\delta^{18}O$ values of finished beads, but since this sample is restricted to whole shell from coastal contexts, heat treatment (with negligible impact on $\delta\ ^{18}O$) is possible, but direct fire exposure can be ruled out as an explanation for unexpected low $\delta^{18}O$ values (Arnold and Rachal 2002; Burns 2019; Milano, Prendergast, and Schöne 2016).

Figure 5 compares isotopic values measured from whole ancient and modern *Olivella* shells from Santa Cruz Island, the only southern California location with a comparable sampling of modern and ancient whole *Olivella* shells (Eerkens et al. 2010). Again, the average isotopic values of ancient and modern serial samples are significantly different (Repeated measure MANOVA, MATS = 38.7, $p = 0.002$). However, the direction of the difference in $\delta^{13}C$ is reversed between the two locations: ancient Central Coast shell is slightly ^{13}C enriched (Figure 4), while on Santa Cruz Island it is ^{13}C depleted relative to modern shell (Figure 5). As a consequence, using modern shell as a reference will tend to assign beads with a Central Coast origin to a southern California source.

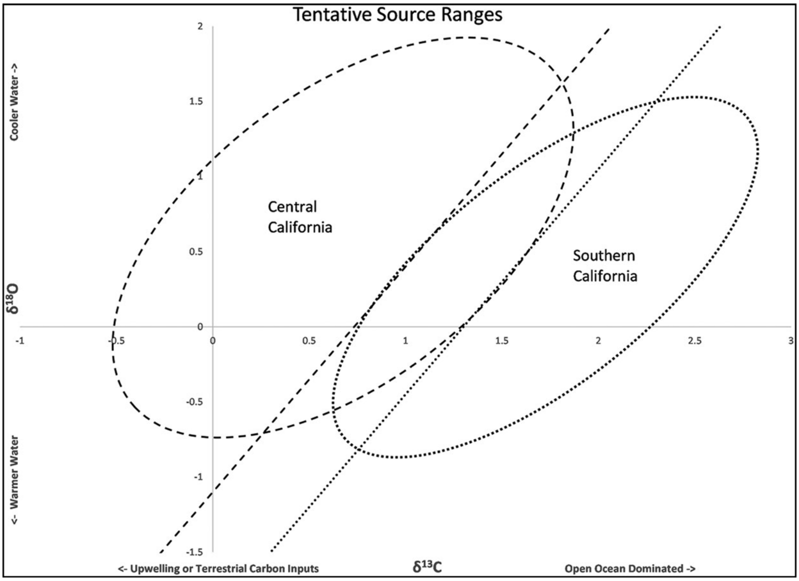

Figure 6. Graphical version of linear functions for source assignment.

Sources of Ancient Beads

Of the 189 ancient beads analyzed in this study, 141 have isotopic values consistent with a central California source, 14 match a southern California source, and 34 have indeterminate values that fall entirely within the range of variation of both sources. Table 1 provides source estimates by bead type. Nine of the tested bead subtypes had at least one example with a southern California source, although in the case of types F3a and G5, beads may have been outliers from type G2 populations. Of the 34 recognized subtypes tested, 28 had at least one example with a central California source. Beads manufactured from central California sources are present throughout the chronological sequence (e.g., L, F, C, M, and E class beads spanning the Early to Mission periods). Although fewer beads from southern California sources were identified, they still represent long-distance conveyance from at least Phase 1 of the Middle Period onward (e.g., types G2b, F3b, D, and E2a). The earliest directly dated bead from central California with a southern California source, a G2b saucer form CA-ALA-413, has a 1σ calibrated date range of 1,617–1,474 BP (Burns 2019, D-1; Groza 2002, CAMS-078740).

Since the training data for southern California beads and shell sources ($n = 67$) is smaller and less evenly sampled than for central California beads and shell sources ($n = 152$), the current study may not adequately capture the full range of variation in southern California sources (Figure 6).

Consequently, it is not yet possible to offer definitive isotopic criteria for separating southern and central sources. Based on the available data, tentative separation is possible through a linear relationship between carbon and oxygen isotopes. Beads where serial samples primarily have values where $1.5\ \delta^{13}C - \delta^{18}O > 1.95$ can be attributed to a southern California source. Beads with a majority of serial samples where $1.5\ \delta^{13}C - \delta^{18}O < 1.1$ correspond to a central California source. Beads with serial samples falling between these values should be categorized as indeterminate. Regardless of linear relationship, beads with serial samples where both $\delta^{13}C$ and $\delta^{18}O$ have negative values suggest an estuarine origin typical of central California (Eerkens et al. 2009).

Discussion

Use of prehistoric materials to define isotopic sources suggests that the majority of beads found in central California were made from local sources, rather than near-exclusive import of material from southern California as suggested when modern shell is used to determine source signatures. Although demonstrating the importance of local central California production, this study also confirms the presence of a significant southern California *Olivella* bead export industry. Morphological and isotopic evidence suggests that beads produced on the Channel Islands dominated trade into the southern Great Basin and at least as far north as the Owens Valley (Eerkens et al. 2005, 2020; Milliken 1999). The results of this study confirm that *Olivella* material was also imported north to the Bay Area in finished, semi-finished (spire-removed beads), or raw form in sufficient quantity to account for 7.4% of all beads analyzed.

Due to limitations in the samples of each bead type, this study is not able to determine the extent to which individual types were a product of local production or long-distance trade, or the extent to which that pattern may have changed through time. However, our results largely support expected sources proposed by Bennyhoff and Hughes (1987): most types with occurrence limited to central California are made from shell collected at central California sources, and where samples were large enough to detect multiple sources, types present in both central and southern California usually derived from both sources.

Isotopic evidence provides limited insight regarding the organization of bead production in central California. Evidence for bead production in the archaeological record and the ethnographic organization of bead production suggest that by Phase 1 of the Late Period (ca. 685 BP), and perhaps as early as the Middle-Late Transition (ca. 900 BP), central California bead production resembled the decentralized political organization characteristic of the region (Bettinger 2015; Burns 2019; Rosenthal 2011). The isotopic space occupied by central California beads is considerably wider than that of southern California beads. This may result from two factors. While archaeological evidence suggests the majority of southern California beads were produced from shell sources on the Channel Islands and a few coastal locations, central California shell sources, as considered here, represent a much wider geographic range and more of the total diversity of coastal environments suitable for *Olivella biplicata*. Additionally, individual environments along the Central Coast and Bay Area have high seasonal variation in terms of freshwater input, upwelling, and water temperature, increasing the isotopic variability present within central California sources.

Consequently, high isotopic variability does not necessarily imply a lack of source concentration. Large production centers may have once dominated the central California bead industry, but are lost to sea level rise, coastal erosion, or Euroamerican development before salvage excavations and modern cultural resource mitigation. However, the similarity in isotopic range between Middle Period Class F beads and Late Period Class M beads in this study suggests that geographic sources for the shells used to manufacture the beads did not shift through time. Since the Late Period is characterized by dispersed production (Rosenthal 2011), a similarity in source may suggest the same was true during the Middle Period, and dispersed production was a foundational quality of the central California bead industry (Burns 2019, 154n37).

Conclusion

The results of this isotopic analysis demonstrate that modern shell does not provide a consistent reference for source determinations of ancient shell from the California coast. Source estimates based instead on cluster analysis suggest that the majority of *Olivella* beads recovered from central California were produced from shell harvested from the Central Coast or Bay Area, but that conveyance from southern California also contributed to the bead supply. Based on bead chronology and direct dates on sourced beads, transport of southern California shell into central California was in place by the end of Phase 1 of the Middle Period (ca. 1,545 BP). Bead production in central California appears decentralized relative to the large production workshops of the Channel Islands, a difference that likely reinforced the divergent sociopolitical trajectories of the regions.

Notes

1. Although many recent archaeological publications use the genus *Callianax*, the taxonomic classification of the genus is controversial, with morphological phylogeny elevating the subgenus *Callianax* (Adams and Adams 1853) to full genus status (Powell, Vervaet, and Berschauer 2020) while genetic phylogeny

retains *Olivella* (Swainson 1831) pending further study (Kantor et al. 2017). With acknowledged participation as a pawn in heated phylogenetic battles, we here retain the use of *Olivella* for both artifact type and genus for consistency with archaeological literature and out of parsimony until the matter is resolved.

2. The analysis of beads to be sourced in this study is primarily limited to wall beads – beads manufactured from a portion of the outer shell wall, as opposed to beads manufactured by modification of the whole shell (e.g., spire-removed beads) or from the callus or columella. Wall beads represent a finished product with relatively high manufacture input (as opposed to spire-removed beads), and incorporate the growth bands required for serial sampling (unlike callus and columella). However, end-ground beads (types B1 and B2), made by more intensive modification of the whole shell, are included. Lipped beads (Class E) are also included, even though they incorporate a portion of the callus, but only the wall section of the bead was sampled.

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