OBSIDIAN TRADE AT SAND HILL BLUFF

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This paper reports new radiocarbon dates, obsidian sourcing, and obsidian hydration data from the 2008 excavations at CA-SCR-7, aka Sand Hill Buff, on the North Central Coast in Santa Cruz County. The 2008 obsidian sample (n = 24) is augmented by surface collected obsidian artifacts (n = 20) recently returned to the public domain. Tentative findings from the only other controlled excavation at Sand Hill Bluff (Jones and Hildebrandt 1990) regarding the nature of obsidian exchange and regional trade affiliations during the Middle period are tested.

Establishing and refining regionally distinct cultural chronologies has been a long-term goal for many California archaeologists. Studying the distribution of exotic goods, especially obsidian, and radiocarbon dating have been important tools when working toward this goal. Archaeologists working along the North Central Coast (defined as extending from the Pajaro River north to the coastal terminus of the San Francisco peninsula) have developed tentative cultural chronologies and trade patterns. Unfortunately, these interpretations have been limited due to the small number of sourced obsidian artifacts, radiocarbon dates, and large-scale excavations. In this regard, further radiocarbon dating of material from appropriate contexts, obsidian sourcing, and hydration readings are needed to refine local chronologies and gain a better understanding of regional trade patterns in exotic material such as obsidian. This project will undertake the analysis of new material excavated from Sand Hill Bluff (SCR-7), a Middle Holocene site on the North Central Coast. I use the new data to test tentative interpretations by Jones and Hildebrandt (1990) regarding obsidian use at the site over time and the relative strength of exchange networks.

In the summer of 2008, students from Cabrillo College, in conjunction with California State Parks, excavated portions of SCR-7 during an archaeological field school. An obsidian sample (n = 24) from three control units is the basis for testing the findings from a smaller sample (n = 14) by Jones and Hildebrandt (1990)—the only other controlled excavation of the site. This paper presents new data from radiocarbon, obsidian sourcing, and hydration analysis relative to those previous findings. An additional comparative collection (n = 20) of surface-collected obsidian is also used in parts of the analysis.

BACKGROUND

Sand Hill Bluff is an extensive prehistoric shell midden located on the coastal terrace 8 km, or 5 mi., northwest of Santa Cruz, California (see Figure 1). At this location, the coastal terrace is about 65 ft. above mean sea level (AMSL). The archaeological geography of the site can be summarized as three elements: Locus 1 is the main portion of the site and consists of a large dune structure containing two distinct prehistoric cultural strata. The dune rises approximately 45 ft. above the coastal terrace. Locus 2 is flat midden located to the south of Locus 1 in an area now under cultivation. Locus 3 is a smaller dune structure to the north of Locus 1 that rises about 20 ft. from the top of the terrace. Locus 3 has yet to be analyzed in any detail, but is thought to contain similar cultural deposits as found in Locus 1 (Hildebrandt et al. 2006). With the entire site located very near the bluff face, the west-facing portions of Loci 1 and 2 are exposed and impacted by erosion of the bluff into the Pacific Ocean (see Figure 2).

A modest series of radiocarbon dates suggest that Sand Hill Bluff was first occupied about 5,500 years before present, at the transition between what has been called the Milling Stone horizon (10,000-5500 B.P.) and the Early period (5500-3000 B.P.). The main period of occupation appears to be during

Figure 1. Sand Hill Bluff (CA-SCR-7) on the North Central Coast. (Source: County of Santa Cruz GIS.)

the Early and Middle periods (5500-1000 B.P.), with some indications of a late occupation to about 700 B.P. (Hildebrandt et al. 2006). Table 1 depicts a regional chronology for the Central Coast of California.

While older sites along the coast of California have been found that appear to significantly predate SCR-7, most notably those in southern California in and around the Channel Islands, the site continues to play an important role in regional chronologies as one of the oldest sites on the North Central Coast (Moratto 1984). Sand Hill Bluff was added to the National Register of Historic Places in 2006.

PREVIOUS INVESTIGATIONS

The first published reference to the Sand Hill Bluff site appeared in 1873 in meeting minutes of the California Academy of Sciences. Dr. A. W. Saxe reported finding a 12-to-15-ft.-thick midden containing projectile points and other flaked stone artifacts as well as a crescent-shaped knife. The site was formally recorded by representatives of the University of California in 1950 (Hildebrandt et al. 2006).

In 1973, paleobiologist G. Victor Morejohn of San Jose State University conducted a limited excavation of the site in search of faunal remains. His report included the discovery of Middle Holocene age remains of an extinct flightless duck (*Chendytes lawi*) and two radiocarbon dates from mollusk and barnacle shells. The shellfish from the upper component produced a measured age of 3780 ±95 years B.P. The lower component produced a measured age of 5390 ±100 years B.P., establishing the site as one of considerable antiquity (Morejohn 1976). These samples have been recalibrated by Gary Breschini using Calib 4.3; the intercepts for these two samples are 3971 and 5940 B.P. respectively.

Hylkema (1991) analyzed 108 projectile points collected by local pothunters from the site's dunes and cultivated fields. While obsidian points represented a significant portion of the collection, none of the points were sourced or subjected to obsidian hydration testing. The study focused instead on the use of point typologies as temporal markers in testing the forager and collector adaptive modes proposed for the Monterey Bay area a decade earlier (Dietz and Jackson 1981) following Binford's (1980) description of the two settlement systems. Hylkema concluded that a generalized foraging strategy, thought to have been replaced by more elaborate collector strategies during the Middle period in many locations, persisted at Sand Hill Bluff through the Middle period to the Late period (Hylkema 1991).

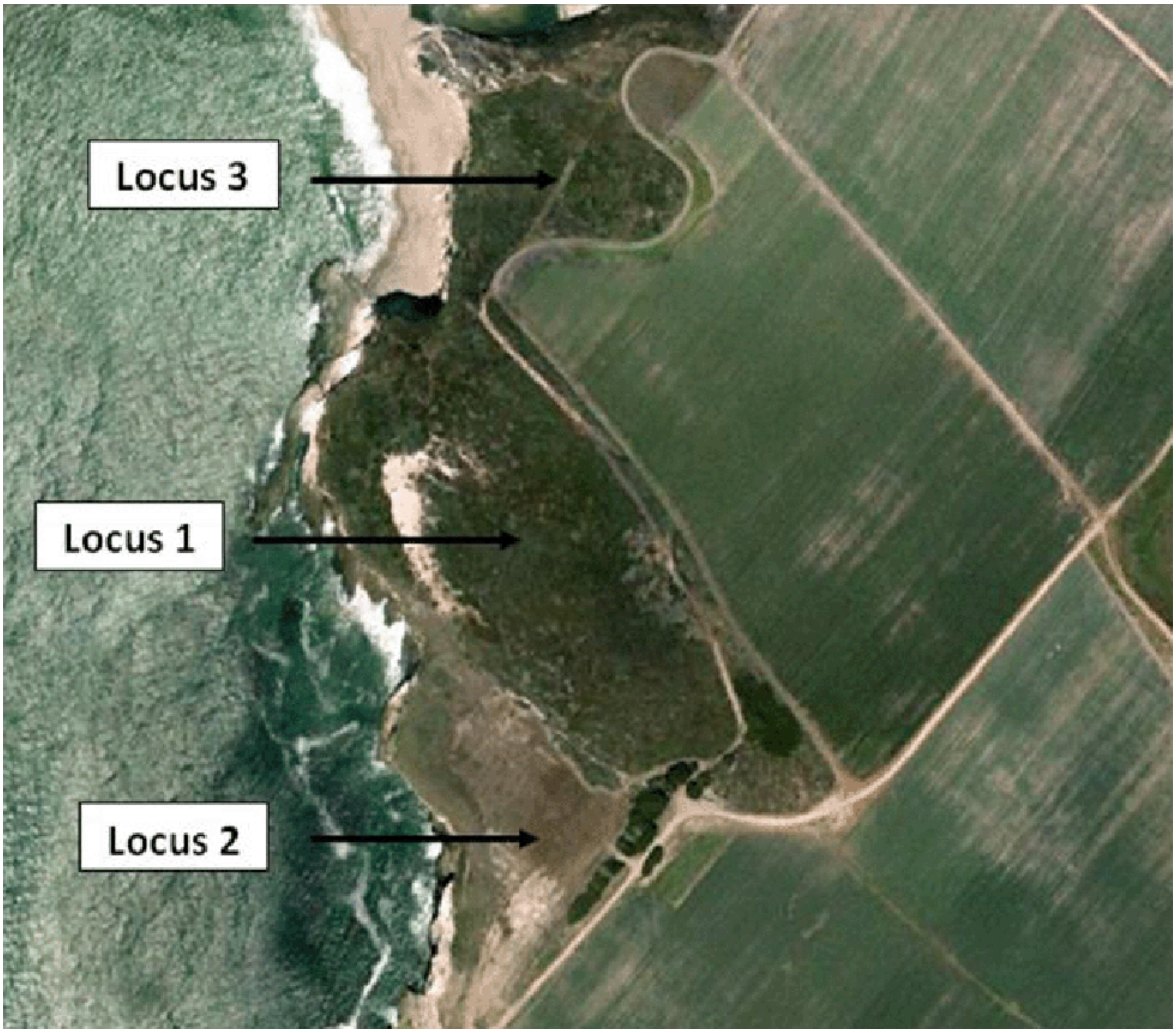

Figure 2. Sand Hill Bluff (CA-SCR-7) aerial view with site geography. (Source: County of Santa Cruz GIS.)

Table 1. General cultural chronology of the North Central Coast (adapted from Hildebrandt et al. 2006).

Cultural Period	**Dates (B.P.)**
Late Period	1000 - Contact
Middle Period	3000 - 1000
Early Period	5500 - 3000
Milling Stone Horizon	10,000 - 5500
Paleo-Indian Period	Pre-10,000

The first controlled excavation of the site occurred in 1988 as part of a California Environmental Quality Act (CEQA) project by Far Western Anthropological Research Group in response to a proposed abalone farm on the bluff. Eventually, a survey, test excavation, and a data recovery-mitigation excavation program resulted in the analysis of over 20 m^3 of material from Loci 1 and 2. The project resulted in far greater clarity with respect to the two temporal components of the site—a basal Early period stratum marked by large amounts of shellfish debris dominated by mussel, an abundance of Monterey chert debitage, and no obsidian debitage or tools; and a superimposed Middle period stratum marked by significantly less shellfish debris, a similar abundance of Monterey chert, and a small amount of obsidian (Jones and Hildebrandt 1990). Both strata contained remains from a broad spectrum of both marine and terrestrial mammals, consistent with the forager adaptive mode.

The study produced one radiocarbon date from a stellar sea lion (*Eumetopias jubatus*) bone found at 80-90 cm in Loci 1. The sample returned a measured age of 5970 ±120 B.P., the oldest basal date for SCR-7 yet recorded. This radiocarbon date has been recalibrated by Gary Breschini to 6308 B.P. (Breschini, personal communication 2010).

A sample (n = 14) of obsidian artifacts (12 pieces of debitage and two bifaces) was recovered and subjected to sourcing and hydration analysis. Results concluded that the obsidian had three points of origin—two from the North Coast Ranges (Napa, n = 9, or 64 percent; Annadel, n = 1, or 7 percent) and one from the eastern Sierra Nevada (Casa Diablo, n = 4, or 29 percent). Eleven specimens yielded hydration readings, and three specimens of Napa obsidian were tightly clustered (3.3, 3.4, and 3.5 microns), suggesting a Middle period occupation based on a conversion factor that equates a Napa obsidian hydration range of 2.3-4.1 microns to 1000-2800 B.P. (Jones and Hildebrandt 1990). Interpreting the data in regards to trade activities, Jones and Hildebrandt concluded that

> obsidian use during the Middle Period was apparently confined to the casual importation of finished tools that were later retouched at the site. While Napa flakes dominate the assemblage, the sample size is too insignificant to confidently attribute this factor to strong exchange networks and affiliations with North Coast Range groups and/or resource procurement trips into these northern territories [Jones and Hildebrandt 1990:54].

RESEARCH DESIGN AND THEORETICAL BACKGROUND

Research Design

This project addresses the question: *What was the nature of obsidian exchange at Sand Hill Bluff?* The study uses an approach that situates the obsidian recovered in 2008 from the untested southeast portion of the main dune structure (Locus 1) in a direct comparison with the smaller obsidian sample collected in 1990 by Jones and Hildebrandt. Radiocarbon dating is used to confirm the antiquity of the site in this location. Material patterning of source-specific obsidian under the temporal control provided by obsidian hydration measurements is used to analyze the obsidian, as was the case for the smaller obsidian sample obtained in 1990 by Jones and Hildebrandt. Lithic technological analysis is also employed to characterize the obsidian collection in detail. The comparison of the two samples will support corroboration, amplification, or redirection of the 1990 findings, which have been restated in the specific research questions below:

- Does the untested southeast portion of the main dune structure, Locus 1, at Sand Bill Bluff date to the Early period as predicted by Jones and Hildebrandt's (1990) stratigraphic description?
- Was Napa obsidian (specifically) and North Coast Range obsidian (generally) dominant at Sand Hill Bluff over other source locations?
- Were finished tools or less formed tools imported and worked at the site?

- Does the temporal distribution of obsidian by source suggest larger patterns of exchange networks or trade affiliations over time at Sand Hill Bluff?

Theoretical Background

Hunters and Gatherers. As a means of mediating between the past and the present using the independent data presented in this study, it is helpful to consider the concept of middle-range theory. Given the setting and period of the present study, it seems appropriate to use Binford's (1980) description of the dynamic patterns of foragers and collectors and how their material remains would be recognized as such in the archaeological record. This approach would also remain consistent with previous approaches to the study of subsistence strategies in the region of Sand Hill Bluff (Dietz and Jackson 1981; Hylkema 1991), as well as the study of the site (Jones and Hildebrandt 1990).

According to Binford, foragers are small highly mobile groups that "map on" to resource areas in a daily quest for food and where storage of food is limited to immediate needs. Foragers find food on an encounter basis during short procurement trips. Procurement trips radiate from "residential bases" that are used until the resources of a given area have been exhausted. Residential moves are frequent and likely to correspond to patches of abundant water and diverse resources. The availability of water or particularly desirable food supplies may "tether" forager groups to certain areas, contracting the overall area of seasonal rounds. Redundant use of residential bases is correlated with the accumulation of materials related to processing and maintenance activities that increase archaeological visibility, such as exotic trade items, hearth features, stone tools and debitage, and food processing tools and debris. By contrast, evidence of procurement trips would be limited due to the fact that functionally specific "locations," such as kill sites, are occupied for very short periods and likely have little redundant use from year to year.

Collectors have an increased logistical approach to subsistence in the form of the storage of food for seasonal use and the deployment of "task groups." Task groups are small parties of skilled people with specific resource collection goals that make it possible for the main social group to be located near productive areas while still exploiting other productive areas for specific materials. To do this, task groups detach from the main group for longer periods than forager procurement parties, setting up "field camps" to serve as temporary home bases during resource collecting activities. Task groups also use "stations" for logistical controls such as observing game or coordinating collecting activities as well as "caches" for storing large bulk resources for later use by the larger social group. Residential moves by collectors are less frequent, owing to the use of task groups to increase resource exploitation in a single location; however, winter and summer accommodations still make sense given the annual cycles of major plant and animal communities and seasonal climate variation.

Forager and collector strategies are combined to varying degrees on a graded scale of characteristics from simple to complex. Collectors will be foragers and also organize logistical operations in increasingly complex adaptations. As logistical complexity increases, intersite variability similarly increases (Binford 1980).

Geochemical Sourcing and Obsidian Hydration. The theoretical basis of geochemical methods used in the study of artifacts and exchange systems can be thought of as having two parts. The first part is not particularly complicated, provided one can trust to the hard sciences certain details of the periodic table not typically found in the archaeologists' tool kit. Specifically, there must be a way to "read" the elemental signature of a particular material (Shackley 2005). Fortunately for archaeologists, the motivation for the development of such methods has existed in the field of geology for many years. These methods, based on the principles of physics, chemistry, and earth science, have steadily increased in number and accuracy since the first identification of archaeological materials by petrographic analysis in 1948, and their increasing usefulness is strongly associated with a dramatic increase in the study of prehistoric exchange and trade in the past 25 years. Today the list of techniques is impressive: neutron activation (INAA), x-ray fluorescence (XRF), proton-induced x-ray emission (PIXE), thermal ionization mass spectrometry (TIMS), among others (Glascock 2002).

The other part of geochemical characterization theory, the Provenance Postulate, is far more intuitive than subatomic particles, and just as important. Proposed by Weigand et al. in 1977 and restated in 2001 by Neff, the concept is a requirement for successful sourcing by chemical differences (Glascock 2002). The Provenance Postulate states: “Sourcing is possible as long as there exists some qualitative or quantitative chemical or mineralogical difference between natural sources that exceeds the qualitative or quantitative variation within each source” (Neff 2001:107). Provided the postulate is true for a particular set of obsidian sources, reading the “fingerprint” of obsidian artifacts by the methods listed above yields a tangible connection between source and site that is invaluable to the study of exchange.

If the Provenance Postulate is a minimum requirement for a material to be reliably sourced, then obsidian gets a high grade. As Michael Glascock wrote in the introduction to his edited book *Geochemical Evidence for Long-Distance Exchange* (2002), among materials typically characterized in provenance studies “obsidian represents the ideal archaeological material useful for sourcing. Individual obsidian sources are highly homogeneous, but the differences between sources are so significant that they can be easily observed by any of the several analytical methods” (Glascock 2002:2).

Accounting for this fortunate fact is the comparatively simple and abrupt genesis of obsidian as an igneous rock. Obsidian forms when high-silica magma is extruded during periods of volcanic activity. The magma finds paths to the surface through existing rock that imparts particular trace elements and minerals that later serve to identify the obsidian. That most extrusive events are short in duration is critical to increasing the homogeneity of the extrusion, since the chemical composition of both the magma and the matrix through which it passes can remain essentially constant throughout the event. Rapid cooling at the surface also contributes to the lack of intra-source variation, as there is little time for newly extruded material to mix with other material at the surface (Monroe and Wicander 2001).

While it is possible to source other lithic material found in archaeological sites such as chert, steatite, and basalt, the more complex geologic history of these materials makes sourcing more complicated and far less reliable. Similarly, material that has been physically and chemically altered during human modification, such as fired clay or smelted metal, proves difficult to source to its original location (Glascock 2002).

Obsidian has another unique property that affords great opportunity for researchers. Over time, obsidian absorbs water molecules from the atmosphere that can be viewed and measured in cross section with high magnification. In 1960, geologists Friedman and Smith discovered “hydration” as they studied the various properties of volcanic glass from around the world. During this work they noted the correlation between age and the growth of “hydration bands” that are measureable intrusive layers of water molecules on the exterior margins of obsidian specimens. They combined this information with their further recognition of the association between obsidian and perlite, the amorphous volcanic glass with high water content (3.5 percent) that forms naturally through the hydration of obsidian. Perlite eventually spalls from the non-hydrated obsidian core (0.1 to 3.3 percent water) when the hydration band approaches 40-60 microns. Taken together, this information suggested that the hydration of obsidian was continuous and therefore predictable. Friedman and Smith published the article “A New Dating Method Using Obsidian: Part I, the Development of the Method” (1960), wherein they presented their discovery.

Freidman and Smith proposed a mathematical model of the hydration rate that could be used to derive estimated dates when new margins on obsidian specimens had been first exposed to the atmosphere. Where obsidian is found in association with archaeological sites this has come to mean when obsidian has been most recently modified by humans. This model ($T = k x^2$), where T is years before present, k is a constant, and x is the hydration band thickness in microns, is described as a diffusion reaction (Friedman and Smith 1960).

Prehistoric Exchange. As noted above, the proliferation of exchange studies is related to the development of reliable high-resolution geochemical sourcing and new dating methods (Shackley 2005). The increase is also associated with the recognition by archaeologists at about the same time that exchange in prehistory is “central to maintenance and change in cultural systems” (Earle and Ericson

1977:3). This view of material exchange as integral to cultural studies reflects a functionalist perspective frequently focused on economic rather than social implications (Jackson 1986). Mathematical modeling has also been an area of concentration, forwarded by researchers such as Renfrew (1984).

Ericson (1977) developed the notion that a group's local environment, and specifically what it does and does not offer in the form of needed supplies, is one of the principal drivers in the development of exchange systems. For example, Ericson analyzed 10 obsidian sources in California and eastern Nevada and the obsidian specimens recovered for 52 sites of similar antiquity throughout the same area. The resulting synagraphic contour map showed clearly the obsidian exchange systems functioning at the time. He then superimposed the location of three variables: prehistoric trails, the geography of alternative lithic material sources (Franciscan chert, Monterey chert, and the Sierra Nevada granite and non-granitic formations) and the ethnolinguistic groups as formulated by Kroeber (1925). By far the closest correlation explaining the shape and intensity of the exchange systems was the presence of locally available alternative lithic material. That is, the exchange systems attenuated where local material was abundant and proliferated where it was not (Ericson 1977).

This theoretical thread is particularly germane to the present study, as Sand Hill Bluff is situated atop a significant deposit of Monterey chert. Abundant quantities of Monterey chert at Año Nuevo just 6 mi. north of the site were managed by local people and likely added to the region's independence from groups with access to other lithic materials such as obsidian and Franciscan chert (Hylkema 1991). The minute quantity of obsidian at Sand Hill Bluff therefore has a functional explanation and may help characterize the nature of obsidian trade as it developed over time.

As another result of better geochemical characterization methods, Renfrew began highlighting regularities involving classes of artifacts, including pottery and chipped stone, and the procurement of the associated raw material from a distance. The most rudimentary regularity is where raw material is highly localized and the abundance of the material in archaeological contexts decreased with distance—what Renfrew generalized as his "Law of Monotonic Decrement" (Renfrew 1984:135). Renfrew saw in this fairly obvious generality the ability to model the "fall-off" curve mathematically in much the same way geographers describe distance decay effects, thereby making interesting variations of the phenomenon detectable, and further, perhaps then being able to associate variations with economic and social processes. Essentially, the math is an algebraic description of the curve created when the measure of commodity abundance is plotted against the distance between sites and a particular source. To the extent that predictive models from different times and places share similarities and differences, much might be said regarding the similarities and differences of the generative economic and social forces associated with them (Renfrew 1984).

To the degree that ancient geologic deposits and fall-off models might still leave many uncorroborated details about trade networks, Jackson (1986) attempted a rigorous combination of geochemical methods and spatial analysis of obsidian artifacts to complement the ethnographic record in late-period north-central California. This was a major departure from the previous generation of California exchange studies such as Davis (1974), where the goal was simply to catalog which groups traded with each other and what materials and products were traded. Jackson's goal was to explore economic organization, cultural complexity, and commodity exchange across territorial boundaries through geochemical and physical analysis of obsidian. The data were combined with ethnographic data generally lacking in detailed descriptions of exchange, but relatively informative regarding ethnic boundaries that might explain geographic patterns of archaeologically recovered obsidian.

The study, performed at a much smaller scale than Ericson's California and Nevada study and within one node of obsidian source abundance (North Coast Ranges), noted that obsidian was imported despite available local materials, traded in a variety of forms (finished tools, partial artifacts, raw material) across some boundaries and not others, and exchanged largely in coincidence with marriage between tribal elite. Exchange was centered on the elite in "primary groups" that controlled principal obsidian sources and that produced obsidian in quantities well in excess of their own needs. Social relations extended from elites through marriage and were a major determinant of direct trade with other groups to a radius of approximately 40 km. This supported the view that native societies in the region of the North Coast Ranges were non-egalitarian and that obsidian production and trade were affected more by social factors than by utilitarian considerations (Jackson 1986).

Focusing on the antiquity of trade, Fitzgerald et al. (2005) reported *Olivella biplicata* shell beads 365 km from the coast, suggesting that ancient trade between the southwestern Great Basin and the central coast of California dates to between 10,300 and 10,000 cal B.P. Early coastal people had apparently established trade in *Olivella biplicata* shell beads with interior groups within only a few millennia of the earliest evidence of coastal peoples on the central California coast (13,000-12,000 cal B.P.) (Erlandson 1994). While the authors acknowledge the possibility that the deposition of the shell beads in the interior was the result of wide-ranging terminal Pleistocene groups that included the coast in their travels, they attribute the find to at least one incidence of exchange between independent groups—the earliest evidence for such exchange.

METHODS AND MATERIALS

Fieldwork

The Cabrillo College field school excavations at SCR-7 began on July 5, 2008. Students excavated four 1-x-2-m units and one column sample per unit. Units 1-3 were located in the southeast portion of the site, on the margin of Locus 1 as it transitions into the level marine terrace. A fourth excavation unit from 2008 was located at Locus 3 in the north portion of the site. All units were hand-excavated in arbitrary 10-cm levels measured from a unit datum. Excavated soils were screened in nested 1/4-, 1/8-, and 1/16-in. mesh screens on site.

Laboratory Methods

Sorting. Students sorted the bulk 1/4-in. material from Units 1-3 into the following categories: bone, shellfish, chert flakes, obsidian flakes, flake tool, biface, projectile point, shell beads, and fire-affected rock. Flaked stone debitage, bone, and formal artifacts were weighed and counted. The 1/4- and 1/8-in. column samples for these three units have also been sorted into the same categories. In addition, the shellfish and the bone from the column samples have been speciated into eight and three subcategories, respectively. The material recovered from Unit 4 remains unsorted.

Lithic Analysis. Laboratory efforts produced an obsidian sample of 24 flakes of debitage. Students weighed the specimens and attempted a basic technological evaluation. At this time, the assignment of lithic flakes into nominal categories of the lithic reduction process is quite standardized. The decision to assign a specific flake to a certain category was based on typological discussions with Dustin McKenzie, Archaeology Instructor, Cabrillo College, as the flakes were recovered during the sorting operation.

Within an SPSS (version 17.0) statistical software database for the obsidian specimens, two variables were defined to describe the 24 flake specimens. The first variable is a common technological segregation of three categories based on the observed cortex on each flake. Student technicians examined each flake carefully using 3X and 5X magnification for the presence of cortex, recording a category for each flake. The flakes were listed as primary (nearly 100 percent cortex on the dorsal aspect); secondary (some cortex on the dorsal aspect); or tertiary (no cortex).

A finer breakdown of the sample is noted in a second diagnostic variable based on the morphology of the specimens. This variable has five nominal categories representing different technological attributes that are understood to be somewhat subjective: percussion flake, early biface thinning flake, late biface thinning flake, pressure flake, and shatter. A percussion flake as defined here has a broad bulb of force and is thick from the dorsal to the ventral aspects relative to its longitudinal length. An early biface thinning flake has a single-facet platform and a simple dorsal topography, while a late biface thinning flake has a multifaceted platform and a more complex dorsal topography. Pressure flakes are quite small and have a simple dorsal topography with a single-facet platform. Shatter is the waste product of the lithic reduction process. Fragments of shatter lack any of the above diagnostic attributes of flakes.

Obsidian Sourcing. The obsidian specimens from the 2008 Cabrillo excavation were sourced using energy dispersive x-ray fluorescence analysis performed by Richard Hughes at the Geochemical Research Laboratory in Portola Valley, California. While obsidian tools are typically large enough to permit artifact-to-source attributions on the basis of correspondence in diagnostic trace element concentration values, Hughes concluded that all of the obsidian specimens from SCR-7 "were too small and thin to generate x-ray counting statistics adequate for proper conversion from background-correcting intensities to quantitative concentration estimates." Instead, sourcing was based on "integrated net count intensity data for the elements Rb, Sr, Y, Zr, Nb, Mn, and Fe" (Hughes 2010:1).

A supplementary collection of surface collected specimens was lent to the project by Gary Breschini, Archaeological Consulting, and Mark Hylkema at California State Parks. The collection is hereinafter referred to as the "Surface Collection." This data set consists of four small flakes collected in the 1980s from the top of the main dune structure of Locus 1, and 16 point fragments collected by local pothunters from throughout the site. The point fragments have been recently acquired by State Parks from local collectors and thus are now available for study. All 20 specimens were visually sourced by Tom Origer at Origer's Obsidian Laboratory (OOL). Given the nonrandom methods by which the point fragments were recovered, only limited use is made of this collection in this study.

Obsidian Hydration. Tom Origer performed hydration testing on the 2008 Cabrillo obsidian samples at OOL. The author performed hydration testing on the supplementary sample at the San Jose State University Obsidian laboratory; however, all results were verified by Tom Origer at OOL. Only 16 of the 20 specimens in the Surface Collection yielded hydration readings. In both cases, laboratory procedures used to cut and mount the obsidian thin sections on slides conform generally to the method suggested by Friedman and Smith (1960). Hydration measurements for each specimen are an average of six readings from each thin-section margin using a 40X objective and a 12.5X eyepiece mounted on a polarizing microscope.

The conversion of mean micron values into years B.P. is based on the diffusion rate equation ($T= k x^2$) (Friedman and Smith 1960), where T is years B.P., k is a constant defined for the Napa source as 153.4 (Origer 1987), and x is the hydration band thickness in microns. The data were controlled for source using conversion constants between sources (Tremaine 1989) and controlled for Effective Hydration Temperature (EHT) (Basgall 1990) with information from the Western Regional Climate Center.

Radiocarbon Dating. Chronometric dating services from the Center for Accelerator Mass Spectrometry at the Lawrence Livermore National Laboratory (LLNL) provided a suite of four AMS radiocarbon dates for radiometric temporal control. LLNL processed four single shell samples of mussel (*Mytilus californianus*) shell from Unit 2. One sample each came from depths of 90-100, 110-120, 120-130, and 150-160 cm. Calibrated dates were derived by Gary Breschini using Calib 4.3 software for the Intercept BP Delta R 225.

DATA

Radiocarbon Dating

As reflected in the first research question, the accurate dating of the archaeological context excavated by Cabrillo College Field School in 2008 is a high priority of this study. The method of obtaining chronological data from this context was AMS radiocarbon dating. Despite the obvious disturbance to portions of the site by the agricultural land uses, it appears that undisturbed contexts and cultural features are present in at least a portion of the excavated areas of Locus 1.

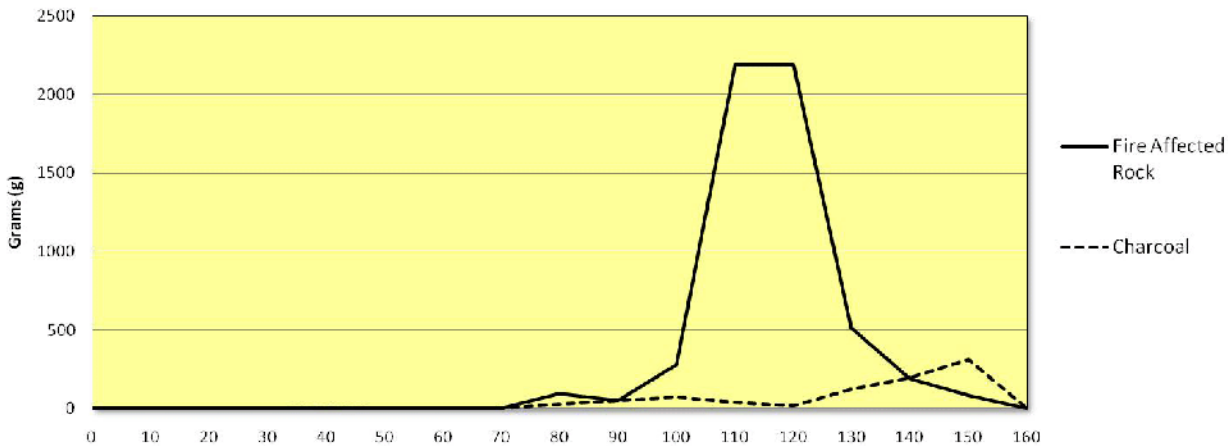

Figure 3. Unit 2 fire-affected rock and charcoal (amplified 100X) by mass.

Specifically, within Unit 2 excavators found an abundance of fire-affected rock (FAR) and charcoal that likely indicate the presence of a hearth feature (Feature 1) between 90 cm and 150 cm. The main constituents of the FAR were 14 rocks of very similar size and shape in a consolidated mass between 110 cm and 120 cm. The mass of rock occupied a space of approximately 0.06 m^3. Anthropogenic soil and dense shell deposit indicative of shell midden completely surrounded Feature 1 and strongly suggest a cultural origin. Figure 3 shows the mass of FAR and charcoal by level. The quantitative measure of charcoal has been amplified by a factor of 100 in order to show the elevated levels of this material in the same graphic as the much heavier FAR. By comparison, the profile of charcoal by mass in Units 1 and 3 is imperceptible even when similarly amplified, underscoring the anomalous nature of the spike in charcoal within all the excavated material as well as its nonrandom co-occurrence with the FAR in Unit 2.

Four AMS radiocarbon dates were generated from four single-shell samples of mussel shell (*Mytilus californianus*) at Lawrence Livermore National Laboratory (LLNL) in Livermore, California. In order to maximize the association with Feature 1, samples were taken from levels 90-100 cm, 100-110 cm, 110-120 cm, and 150-160 cm, thus bracketing Feature 1 while also sampling the base level of the control unit. The results of the AMS dating are presented in Table 2. Dates have been calibrated by Gary Breschini using Calib 4.3 at the intercept BP with Delta R 225.

Obsidian Studies: Sourcing and Hydration

The small size of the flakes necessitated sourcing by integrated net count data for the elements Rb, Sr, Y, Zr, Nb, Mn, and Fe by Richard Hughes, Ph. D., RPA at the Geochemical Research Laboratory for 22 of 24 specimens in the 2008 collection. Two additional flakes were visually sourced by Tom Origer at OLL. Results show 15 specimens (62.5 percent) are from the Napa source, four (16.7 percent) are from the Casa Diablo area of the central Sierra Nevada range, three (12.5 percent) are from the Annadel source in the North Coast Range just southwest of the Napa source, and two (8.3 percent) are from the Mt. Hicks source in western Nevada.

All 24 flakes were submitted to OLL for hydration analysis. One specimen did not have a readable hydration band due to diffuse hydration. The 15 Napa readings have a mean value of 2.9 microns (SD = 0.795), which approximates to 1290 B.P. The very small sample of obsidian from other sources lessens the usefulness of their mean values.

As suggested by the standard deviation for the Napa sample, the hydration readings show a widely dispersed pattern, from a minimum reading of 1.4 microns to 4.5 microns, which equates to a calendrical date range of 345 to 3389 B.P. There is a concentration of hydration readings around the date

Table 2. Sand Hill Bluff (CA-SCR-7) AMS radiocarbon dates from Unit 2.

LEVEL (CM)	LAB NO.[1]	CONVENTIONAL AGE	CALIBRATED 2-SIGMA A.D./B.C. DATE	INTERCEPT B.P. DATE [2]
90-100	CAMS-146093	5390 ±35	3659-3491 B.C.	5559
110-120	CAMS-146094	5605 ±40	3935-3663 B.C.	5732
120-130	CAMS-146095	5605 ±40	3935-3663 B.C.	5732
150-160	CAMS-146096	5670 ±35	3966-3751 B.C.	5850

[1] Lawrence Livermore National Laboratories.
[2] Calibrated using Calib 4.3; Delta R = 225.

of 1000 B.P., with the largest spike at approximately 1200 B.P., which corresponds closely to the mean value for the entire Napa sample. Two discontinuities in the Napa hydration readings are associated broadly with 1500 B.P. and 3150 B.P., as no readings correspond to within approximately 150 years older or younger than these dates.

The two samples from the Annadel source, the other North Coast Range, postdate the peak in Napa values, with dates of 443 and 811 B.P. Similarly, Casa Diablo obsidian (n = 4) shows youthful hydration readings with a concentration of three readings between 742 and 959 B.P. The most recent reading (1.3 microns), corresponding to a date of 221 B.P., is also attributable to the Casa Diablo source. Mt. Hicks obsidian (n = 2) has band readings (3.2 and 3.5 microns) which convert to dates 1118 and 1474 B.P., and are thus somewhat coincidental with the peak in Napa hydration values.

Lithic Characteristics

The obsidian assemblage for the Cabrillo 2008 excavations came from excavation units 1, 2, and 3, located in the southeast portion of the main dune structure, or Locus 1. This assemblage (n = 24) consists exclusively of small debitage, ranging in size from less than 0.01 g to 0.29 g with an average weight of 0.045 g (SD = 0.06). Only one (4.2 percent), the largest specimen (0.29 g), appears to have been removed with percussive force and has therefore been classified as a percussion flake, according to definitions given in the methods section above. When this specimen is removed from the calculated mean, the remaining specimens are very similar by weight (mean = 0.034 g, SD = 0.03) and morphology. All of these small specimens are either late-stage thinning flakes (62.5 percent) or pressure flakes (33.3 percent) as defined above. All specimens, including the one percussion flake, are interior or tertiary flakes with no cortex remaining from the original volcanic deposition of the obsidian.

The Surface Collection contains 16 point fragments, two late-stage thinning flakes, and two pieces of shatter. Of the 16 point fragments, several were noted by Tom Origer during visual sourcing as having been reworked or retouched to some degree. Two specimens in particular seem to have been reworked from broken points to perforators, with wide bases and thickly reduced ends. Such reworking may help explain the very small size of the flakes recovered at SCR-7 in both 1990 and 2008.

DISCUSSION

With the data described above, the research questions stated above can be addressed. The first question was, *Does the untested southeast portion of the main dune structure, Locus 1, at Sand Hill Bluff date to the Early period as predicted by Jones and Hildebrandt's (1990) stratigraphic interpretation?* Regarding the antiquity of the southeast portion of the main dune structure that is Locus 1, the suite of AMS radiocarbon dates presented here (5559, 5732, 5732, 5940 cal B.P.) may be the most compelling evidence yet in support of previously forwarded suggestions (Hildebrandt et al. 2006; Hylkema 1991; Jones and Hildebrandt 1990) that undisturbed deposits exist within the main dune structure. The strong

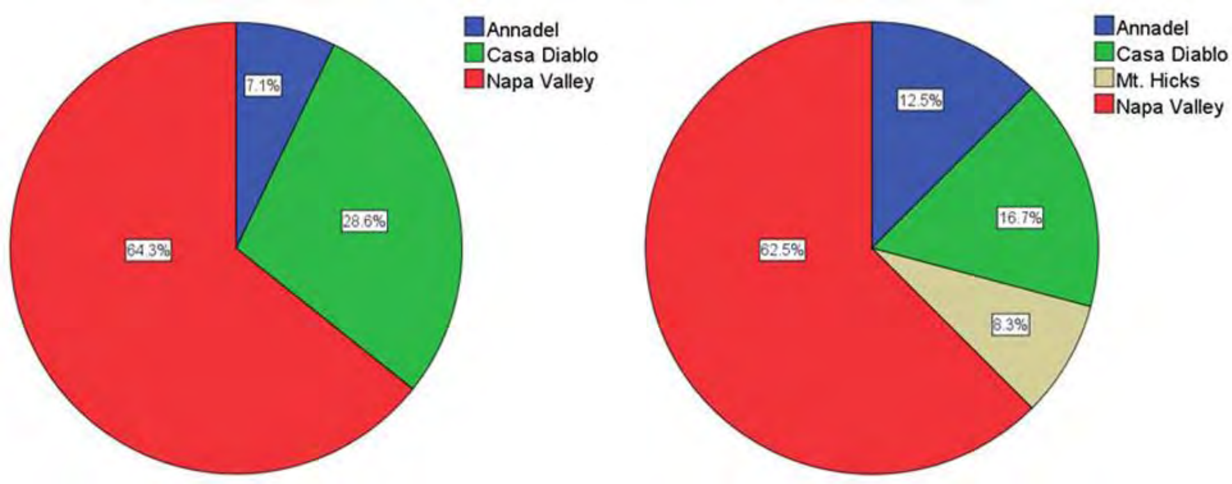

Figure 4. Obsidian source distribution: left, Jones and Hildebrandt 1990 (n = 14); right, Cabrillo 2008 (n = 24).

association of the new data with Feature 1 and the tight grouping of dates in superposition seem to confirm these claims emphatically. At the very least, the antiquity of the previously untested southeast portion of Locus 1 appears equivalent with the area excavated by Jones and Hildebrandt in 1990, recalibrated by Gary Breschini to 6308 cal B.P. Taken together, this is considerable support for human presence at Sand Hill Bluff prior to the Early period, herein defined as 5500 to 3000 B.P., and further, that regular use of the site may in fact have been well established by that time.

The second research question can also be addressed. *Was Napa obsidian (specifically) and North Coast Range obsidian (generally) dominant over other source locations at Sand Hill Bluff?* While the small sample size of the 1990 collection was reason for caution, direct comparison of that sample with the more robust obsidian collection from 2008 suggests that the 1990 sample accurately predicted the percent of Napa source obsidian specifically and North Coast Range obsidian generally at the site. As shown in Figure 4, the source distribution of the Jones and Hildebrandt 1990 collection and the Cabrillo 2008 collection are quite similar. When aggregated, the obsidian permits less tentative statements about the dominance of Napa obsidian in use at Sand Hill Bluff and perhaps also the strength of regional exchange networks and trade affiliations.

Specifically, 62.5 percent (n = 15) of the 2008 Cabrillo assemblage (n = 24) is attributed to the Napa source. A very similar percentage of the 1990 collection (64.3 percent) comes from the Napa source. When combined with specimens from Annadel, the only other North Coast Range source in both collections (Cabrillo [n = 3], Jones and Hildebrandt [n = 1]), the percentages are 71.4 percent and 75.0 percent, respectively. All other obsidian in both cases can be attributed to Eastern Sierra sources (Casa Diablo and Mt. Hicks). These results are also consistent with Hylkema's regional study that included obsidian (n = 137) from eight coastal sites (not including SCR-7) from Santa Cruz and San Mateo counties. He found 76 percent of the specimens were from North Coast Range sites, with Napa representing 63.5 percent of the total sample (Hylkema 1991). Thus, it appears that the small sample size analyzed by Jones and Hildebrandt did not impede the interpretation regarding where the obsidian in use at the site originated. It may well be that relatively strong trade networks or affiliations did exist between groups in the North Coast Range region and groups with a seasonal presence at Sand Hill Bluff.

Testing the third research question involves a more qualitative method of analysis. *Were finished tools or less formed tools the principal obsidian import at Sand Hill Bluff?* Complications exist with a direct comparison of the Cabrillo 2008 and Jones and Hildebrandt 1990 collections with respect to lithic analysis. The lack of specific information regarding the obsidian analyzed by Jones and Hildebrandt in 1990 permits only a partial comparison. In 1990, the specimens were only classified as "debitage" (n =

Table 3. Cabrillo 2008 obsidian by flake type.

Flake Type	Frequency	Percent	Cumulative
Late Biface Thinning	15	62.5	62.5
Pressure	8	33.3	95.8
Percussion	1	4.2	100.0
Total	24	100.0	

12) and "biface" (n = 2). Of the 12 debitage specimens, only 10 are listed in the index catalog with their weight. Only one of these has a mass greater than 0.1 g (0.6 g), with the remaining nine weights recorded as 0.1 g. It may be that this was intended to be <0.1 g, with smaller measurements rounded up to 0.1 g. Despite this ambiguity regarding the mass of two specimens and the lack of qualitative descriptions of individual flakes, the very small size of the majority of the sample is certainly enough to appreciate the general conclusion drawn from the material in 1990: that is, that late stage finishing and retouching of obsidian tools characterized the obsidian production at the site.

As noted above, two variables were used to describe the obsidian flakes from 2008. Regarding the presence of cortex on the flakes, all 24 specimens lacked any cortex from the original geologic context, that is, they are all interior flakes. The technological classification of the flakes shows that all but one of the flakes are either late-stage biface thinning flakes or pressure flakes, with one flake indicative of percussive reduction. The data by flake type are summarized in Table 3.

While direct comparison between the two collections at the level of detail presented for the 2008 collection is not possible, the new flake collection does support a similar conclusion that only late-stage tools were being finished and retouched at the site. There is no evidence that less formed tools were being imported and worked at the site.

Obsidian hydration as chronological control is required to address the final research question: *Does the temporal range of obsidian use by source suggest larger patterns of exchange networks or trade affiliations over time at Sand Hill Bluff?* In support of this question, the analysis is augmented by the Surface Collection (n = 16) described above. For the Cabrillo 2008 and Jones and Hildebrandt 1990 collections, the sample size for the hydration data is smaller, n =23 and n = 11 respectively, owning to several instances where the hydration bands on particular specimens were too diffuse or weathered to provide useful measurements. The one specimen omitted from the Cabrillo collection was from the Annadel source, and the three specimens from the Jones and Hildebrandt collection were from Annadel (1) and Casa Diablo (2).

The three collections are shown together in Figure 5 graphed over time by their estimated hydration date conversions and segregated by source. Several patterns emerge that add to our understanding of the nature of obsidian exchange at the site. The first pattern that becomes apparent is that both the Cabrillo 2008 and Surface Collection show obsidian use at the site much later than the 1990 sample. In fact, the majority of the 2008 Cabrillo sample, 18 of 23 specimens, have hydration readings that convert to dates after 1500 B.P., with a mean value of 925 B.P. So where the 1990 sample led to an interpretation focused on obsidian exchange during the Middle period, the new data suggest that the most intense period of use may have been closer to the Middle/Late period transition around 1000 B.P. This may be significant in that it coincides with other cultural changes suggested by Hylkema (1991, 2002) as taking place at the time. These changes are most notably the transition of coastal groups from a forager adaptive mode that was largely independent from the southern San Francisco Bay area populations to a collector adaptive mode more similar to the south Bay Area, both socially and economically.

Perhaps related to the increase of obsidian in the later period is the increase in the number of sources detected in the new samples. All three new sources (Mt. Hicks, Casa Diablo, and Annadel), beyond the increase in Napa obsidian, seem to either emerge or reemerge at a point around 1000 B.P. As

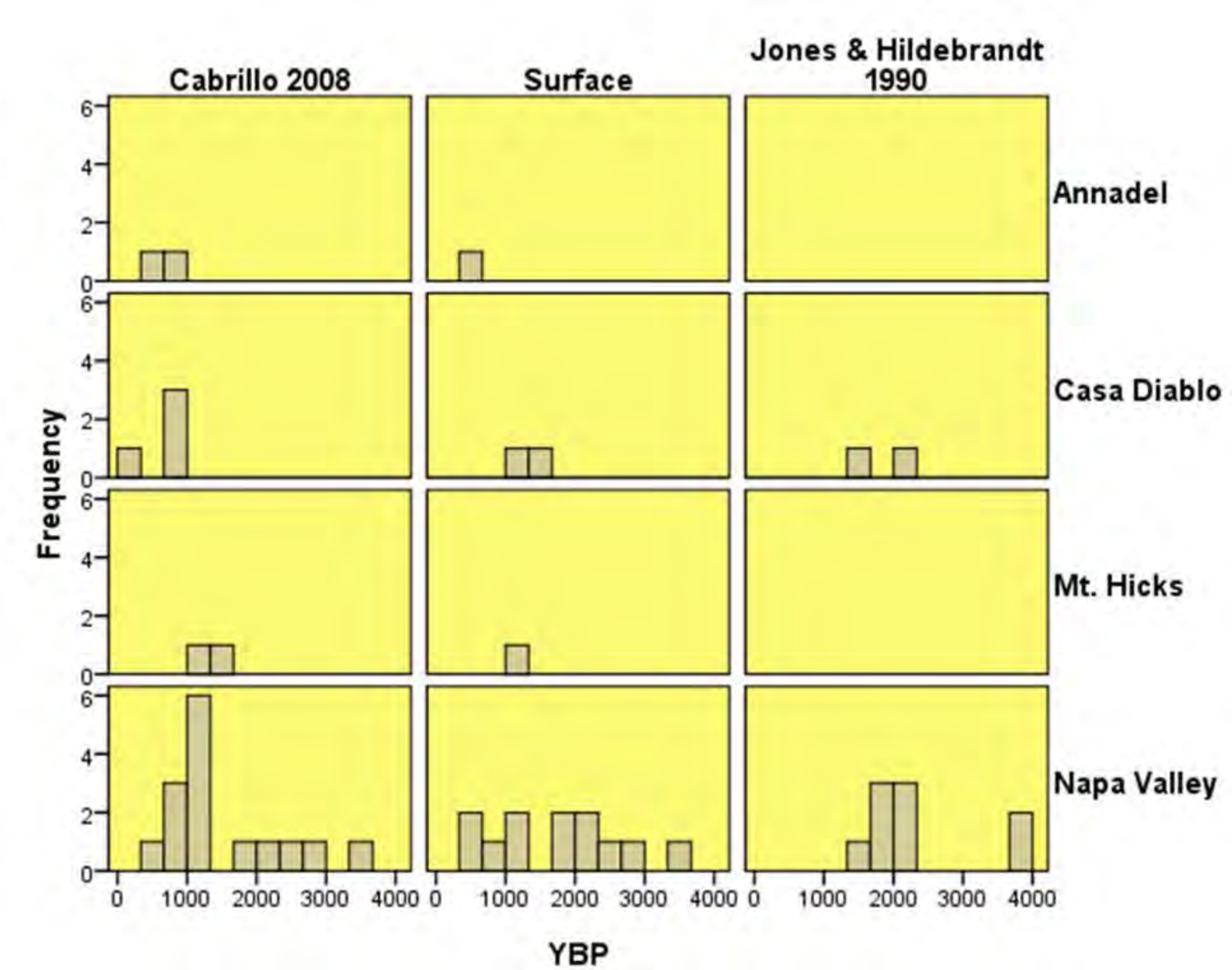

Figure 5. Comparison of three study samples by source and hydration date.

noted above, two Annadel and two Casa Diablo specimens are not included in the hydration data set because they did not yield useful hydration readings. Since all the omitted samples are from these late-emerging sources, the strength of the apparent pattern may be taken as potentially weaker or stronger depending on when these specimens were produced.

This same pattern, however, can be found just over the Santa Cruz Mountains to the east at SCL-65 in Saratoga, where a collection (n = 56) of hydration readings by source indicates a similarly late (ca. 1000 B.P.) concentration of Annadel obsidian (n = 4; 7 percent) where no earlier material from that source is reported (Fitzgerald 1993). The coincidence of this pattern may suggest that whatever changes took place in the exchange networks affecting Sand Hill Bluff and other coastal sites were related to changes taking place in the Santa Clara Valley at the transition between the Middle and Late periods. These changes are noted by Hylkema (2002) as a “florescence” of the southern Bay Area Ohlone groups that included increased interrelation of group economies, increased social hierarchy, refinement of wealth and status, and perhaps most important, increased demand for coastal-specific material to display wealth and status such as *Haliotis* for banjo pendants and *Olivella* shell currency. A line of exchange from the coast through the Santa Clara Valley near SCL-65 would explain the coincidental appearance of Annadel obsidian at Sand Hill Bluff and Saratoga. This seems even more likely given that the increased interrelations of group economies in the southern San Francisco Bay likely resulted in increased economic range for the region (Hylkema 2002). This may have precipitated a first-time intersection or overlap of the expanded South Bay economy and the southern extent of the Annadel distribution pattern to the north, while at the same time increased the economic connections between the coast and the burgeoning demand for *Haliotis* in the Central Valley happening at the same time (Hylkema 2002). The increased range may thus have supported a greater flow of coastal trade goods east and the flow of North Coast Range obsidian south and then west to the coast.

Certainly the above pattern seems more plausible than direct trade from the coastal area of Sand Hill Bluff and the North Coast Range "Primary groups" described by Jackson (1986). These groups traded directly largely within a 40-km radius that coincided with the extent of marriage ties between elites of various groups, and the distance from Sand Hill Bluff to the North Coast Ranges (approximately 200 km) far exceeds this perimeter.

Before this Late period peak in the present data, the flow of Napa obsidian appears somewhat stable and largely uninterrupted, suggesting long-term reoccurring contact between groups with a seasonal presence at Sand Hill Bluff and those with access to a regular supply of obsidian from the Napa source beginning about 4000 B.P. As noted above, this was likely not accomplished through direct trade, but rather through at least one and perhaps several secondary connections. Further, it appears that the relative dominance of Napa obsidian was similarly continuous until the aforementioned Late period increase of obsidian from other sources.

Thus, it does appear that the small sample size from 1990 did somewhat obscure both the breadth of obsidian use at Sand Hill Bluff as well the later diversification of obsidian by source that is shown in both samples in the current study. As a consequence, conclusions by Jones and Hildebrandt were understandably focused on Middle period exchange and did not note the change indicated by the increase in obsidian from different sources in the later period of obsidian use.

CONCLUSION

It has been the goal of this project to be able to more confidently forward statements that describe the nature of obsidian trade at Sand Hill Bluff. In the final analysis, it seems productive therefore to restate the tentative findings by Jones and Hildebrandt (1990) to incorporate the results from the 2008 Cabrillo College excavations and the above analysis.

Given the above data, it seems reasonable to assert that the importation of obsidian at Sand Hill Bluff appears to have been generally uninterrupted from about 4000 B.P. in the Early period and likely transpired through more than one trade group encounter rather than direct trade with groups in control of the obsidian sources. The dominance of Napa obsidian was notable throughout the period of obsidian use, fading only during the Late period when material from other sources became more common. Late period trade affiliations with secondary supplies in the southern San Francisco Bay area are indicated. Imported items uniformly consisted of late-stage tools that were finished, retouched, and recycled at the site.

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