

Transition from Geophyte to Seed Processing: Evidence for Intensification from Thermal Features near China Lake, Northern Mojave Desert

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Abstract

Thermal features containing charcoal, ash, fire-cracked rock, and/or charred seeds are a common component of Late Prehistoric hunter-gatherer sites in the northern Mojave Desert. Although these features have done much to inform site-specific interpretations, particularly regarding diet, an intersite comparison has not been undertaken. Our analyses of shape, size, context, and content suggest these features can be divided into at least four different categories. Temporal patterns in thermal features demonstrate a shift in subsistence pursuits from root, tuber, and bulb (i.e., geophyte) harvesting between 1000-300 BP, to intensive seed processing after 300 BP in the area. While intensification on seeds late in prehistory appears to be a pan-Great Basin phenomenon, a focus on geophytes earlier in time appears to be more local in the Mojave Desert. Climate, population increase, technological innovations, and social factors are likely to account for the dietary shift.

Introduction

The study area is located in southeastern California on the northwestern edge of the Mojave Desert, and is centered around Naval Air Weapons Station (NAWS) China Lake. This region is an arid and marginal environment distinguished by rugged low-lying hills, dry alkaline lake playas, and sparse vegetation, primarily creosote (*Larrea tridentata*), white bursage (*Ambrosia dumosa*), and other drought-tolerant species. Climate is characterized by hot summers (>40° C) and cool winters (<15° C). Lying in the rain-shadow of the

Sierra Nevada, precipitation averages less than 12 cm per year with most years receiving less than 6 cm. Yet, as evidenced by the archaeological record, the Mojave Desert was home to low-density, but relatively stable, populations of people, many of whom may have made only seasonal use of the area (e.g., Eerkens 1999).

While the archaeological record of the Mojave Desert is not particularly diverse or spectacular, it is well-preserved and has a distinctive character that makes it attractive for studying certain aspects of small-scale hunting and gathering populations. Discrete areas containing burned plant materials and/or fire affected rocks are a common component of this record. Over the years hundreds of these thermal features have been excavated, showing significant variation in their shape, size, context, and contents. Such thermal features include formal and prepared circular hearths, as well as more ephemeral scatters of charcoal and ash. Although some of these features may represent the remains of hearths built to generate warmth (i.e., campfires), based on analyses presented below, we believe the majority are the byproduct of cooking activities. This paper attempts to organize functional and temporal variation of such features into a central

framework to address changes in subsistence pursuits in this region.

Ethnographic data on the inhabitants of the Northern Mojave Desert are not as extensive as they are for other regions of the desert West. Descriptions suggest highly mobile hunting and gathering populations made use of this area (Kelly and Fowler 1986; Kroeber 1925; Steward 1938; Zigmond 1981). Indeed, many peoples with more permanent homelands outside the region may have made seasonal trips into the area in small nuclear or extended family groups. Such small groups of people may have stayed in Northern Mojave for short periods of time, especially during spring and early summer, to exploit various seasonally abundant food resources (Eerkens 1999). Extreme temperatures in the height of summer would have made occupation and outside work difficult during this season. Resources that would have been exploited include game such as antelope and lagomorphs and various plants including small seeds, roots, tubers, bulbs, and greens (Fowler 1986).

Background, Methods, and Data Set

Prehistory in the northern Mojave Desert is generally divided into at least six blocks of time. These periods were originally defined by discrete projectile point types, but have been independently verified by subsequent radiocarbon dating (Bettinger and Taylor 1974). This paper is concerned with the latest three periods. The Newberry Period (ca. 3500 – 1500 BP) is characterized by Elko series dart points and the use and production of large obsidian bifaces quarried at the source. Numerous rock art panels were created during this period, and rates of exchange and large-mammal hunting were much increased relative to earlier and later time periods (Bennyhoff and Hughes 1987; Elston and Zeier 1984; Gilreath and Hildebrandt 1997; Hildebrandt and McGuire 2002; Quinlan and Woody 2003). As fewer single-component sites have been excavated from the region (though see Mc-

Guire, Garfinkel, and Basgall 1982; Eerkens 2003b; Gardner 2002; Sutton 1991) less is known about the subsequent Haiwee Period (ca. 1500 – 600 BP) which is distinguished by Rose Springs projectile points. However, group territories and annual rounds seem to have been reduced in size, and bow and arrow hunting was introduced (Bettinger 1989; Yohe 1992). The final Marana Period (ca. 600 BP – contact) is defined by Desert Series arrow points and the introduction of pottery technologies. Sites are relatively ephemeral indicating higher residential mobility, though base camps are also known. Sites frequently contain large numbers of millstones and charred seeds.

For the current analysis, excavation reports from the Indian Wells Valley and the adjacent Coso Range were consulted to create a database of attributes associated with thermal features. Features that lack charcoal, ash, and/or fire-cracked rock (FCR) and that represent the remains of houses were excluded from the study. In total, 141 thermal features were identified and included in the database. The majority of these come from four main areas within NAWS China Lake, including Coso Basin (Rosenthal and Eerkens 2003; n=18), the eastern flanks of the volcanic fields (McGuire and Gilreath 1998; n=13), the Coso Volcanic Fields (Gilreath and Hildebrandt 1997; n=47), and Burro Canyon (Gilreath and King 2002; n=40). N equals the number of thermal features. The remaining 23 features were recorded in scattered projects on and within 30 miles of the north range of NAWS China Lake. All fall within the Mojave Desert proper (135 in Inyo county and 6 in Kern county). Features from Owens, Panamint, and Death Valleys were excluded. Figure 1 presents a regional map showing the location of these areas.

Attributes examined in the current analysis include size (i.e., diameter and depth), configuration (i.e., circular, oblong, etc.), presence or absence of FCR and charcoal, rock types present, environmental context (i.e., landform and vegetation), and the presence or absence of burned bone. When chronological data

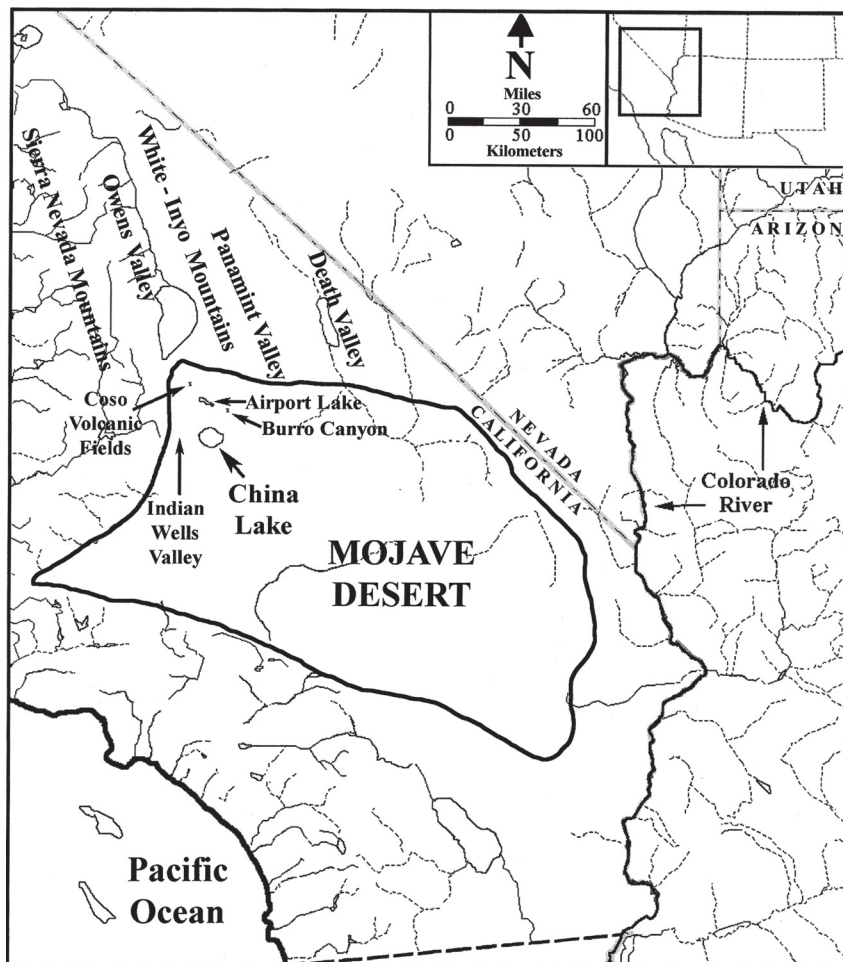


Fig. 1: Map of Northwest Mojave Desert and locations mentioned in text.

and/or macrobotanical remains from flotation samples were available, the age and number of charred seeds and wood charcoal per liter were also included. Fifty thermal features have associated radiocarbon dates, and flotation analyses were carried out on 100 of the 141 features.

Classification of Thermal Features

Our classification focuses mainly on the formality of the feature, the presence or absence of significant FCR, and the quantity of macrobotanical remains present. Four different feature types were defined and divided into two main categories, formal and informal. Formal features (n=44) include those with clear and

pre-conceived design characteristics, that is, where a particular shape and size was intended prior to use. They include pits and pit-hearths. Informal features (n=89) are more a byproduct of use with no foresight in construction and include hearths with seeds and hearths without seeds. One hundred thirty-three of the 141 features had enough information to be classified according to the criterion established below. The remaining nine were classified as unknown.

Pits

The first category represents a formal pit feature. Pits are circular in shape and at least 15 cm in depth, with steeply sloping sides (i.e., greater than 45 degrees).



Fig. 2: Profile of pit feature from Burro Canyon, NAWA China Lake.

Pits also lack a ring of rocks lining the mouth or opening. During construction emphasis was clearly placed on excavation in the vertical dimension, rather than creating a broad surface area for cooking.

Six pit features were identified in the sample. They range in diameter between 0.4 and 1.2 meters, with an average of 0.83 meters and a Coefficient of Variation (CV) of 41%. Coefficient of Variation is the standard deviation of a sample divided by the mean and is a preferable statistic to measure variation because it scales variation relative to the mean (see Eerkens and Bettinger 2001). In depth, they range between 0.15 and 0.8 m, with an average of 0.33 and CV of 81%. These CV values indicate a substantial degree of variation (i.e., dispersion) in pit diameter and depth, suggesting little concern for construction in a standardized manner. This could indicate that pit features were used for a range of different functions, varying in diameter and depth depending on the resources that were prepared or stored in them.

Three are rock-lined on their bottom and three are not, and five of the six have associated FCR. However, only one displays a clearly delineated “toss zone” of

fire affected rocks outside the feature. None are associated with appreciable densities of charred seeds, burned bone, or groundstone. In general, such pits have been interpreted as opened and emptied storage facilities. However, that they show evidence of burning and contain FCR suggests that at least some were used for cooking. Unfortunately, the lack of organic remains precludes determining the types of goods that may have been stored or cooked in these features.

Radiocarbon dates are available for four of the six pits (3080 BP \pm 70, 2450 BP \pm 90, 1450 BP \pm 70, and 670 BP \pm 60). Three date to the Newberry and one to the Haiwee Period, slightly earlier than other thermal features defined below. Figure 2 shows an example of such a feature from Burro Canyon (Gilreath and King 2002).

Pit-Hearths

The second class of thermal feature comprises a formal circular arrangement of rocks between 1.5 and 0.7 meters in diameter, representing a shallow pit-hearth. Thirty-eight pit-hearths were recorded in the current sample, and many more are described by Botkin,

Clellow, Brown, and Clellow (1987) but could not be included in the analysis because of a lack of specific data (i.e., measurements, contents, context, etc). The 38 features average 0.9 m in diameter, with a CV of 28%. Depths are generally shallower than formal pits, varying between 7 and 25 cm, with an average of 15.7 cm and a CV of 32%. The low CVs compared to other feature types connotes some degree of planning or optimal shape and standardization during construction (Eerkens and Bettinger 2001). In other words, these features were probably used in a consistent way

to process a particular food resource, leading to some degree of standardization in size and shape relative to the other features discussed in this paper.

When such features are visible on the site surface, they frequently contain discrete piles or “toss zones” of smaller fist-sized cobbles on one or more sides of the main ring. Of the 36 features that had sufficient data to determine if a toss zone was present, 25 (69%) did. Similarly, of 37 that had sufficient information to determine if FCR was present, 35 (95%) did, frequently in the toss zone.

These percentages suggests that additional rocks (i.e., other than the ones forming the ring) are nearly always associated with these features. Of the 18 for which rock type was recorded, 16 (89%) had granite as the primary rock. Groundstone is not associated with any of the features. Pit-hearths are also frequently lined with smaller rocks on their bottom. Of the 33 features that have sufficient data, 25 (76%) are rock-lined. Figure 3 shows two pit-hearths from Coso Basin, one before excavation and a second after excavation exposing the rock-lined bottom. Note the toss-zones associated with the latter.

The formality of pit-hearths along with the frequent association of toss zones suggests use as cooking facilities, rather than hearths made to generate warmth (i.e., camp fires). We interpret the toss zones as concentrations of cooking stones that were removed from



Fig. 3: Plan views of pit-hearths from Airport Lake Basin, NAWA China Lake.

the interior of a pit-hearth and placed to the side following a cooking event. Such rocks likely represent an indirect reservoir or sink of heat that was added to the pit-hearth. Cooking stones release and distribute their heat over a longer period of time than wood or other sources of fuel. Granite may be the dominant material because it absorbs and stores more heat and releases it over a longer period of time than less dense rock such as basalt, particularly the vesicular variety that is so common in the Coso Basin.

Flotation samples from 31 of the features have been processed for macrobotanical remains. Twenty-seven (87%) had no charred seeds and only one (3%) had more than two. In all cases charred seeds seem to be fortuitously associated with the feature. The lack of seeds is not a result of poor preservation, as wood charcoal is present in moderate to high levels (greater than 1/2 gram per liter of sediment) in nearly half of the features. This information confirms that pit-hearths were not used to process seed resources, a result that is in line with ethnographic data (Fowler 1986; Steward 1938). Ethnographers did not describe the use of formal pit-hearths for processing seeds. Similarly, none of the features or their immediate surroundings contained burned bone, which suggests these features were not used to process meat either. Instead, we interpret them as the byproduct of bulb, tuber, or root processing activities, which rarely survive in archaeological deposits. Throughout the rest of the paper we use the term “geophyte” to collectively refer to these three food products.

That pit-hearths were used to process geophytes is in line with theoretical and ethnographic data from within the region and elsewhere (for a summary see Wandsnider 1997). Shallow pit-hearths are more efficient and better-suited for mass-processing geophytes that contain toxins and complex carbohydrates. Lengthy exposure to the low-level heat given off by rocks helps to break down such compounds, making them more digestible and increasing the amount

of energy obtained from a food source (Stahl 1989; Wandsnider 1997). Use of pit-hearths for roasting geophytes is also known from the ethnographic literature in the Great Basin (e.g., Drucker 1937:10; Kelly 1932; Lowie 1909, 1939; Steward 1941:333). Interestingly, pit-hearths in the China Lake area are often found isolated from other artifactual debris dating to the same time period, though such features often occur in clusters. This suggests that geophyte processing often took place at some spatial distance from habitation sites (consistent with Thoms 1989:290-291).

Radiocarbon dates are available for 19 of the 38 pit-hearth features. Dates range from a single modern reading to 1730 ± 90 BP, though the vast majority ($n=14$) fall between 290 and 930 BP. These dates suggest that these features date predominantly to the late Haiwee and early Marana periods. Whether geophytes were more common during this time, prompting the construction of many such processing features, or more formal features were simply preferred over informal ones by inhabitants occupying the region between 290-930 BP (i.e., whether environmental or cultural factors are behind their restricted temporal distribution) is considered in greater detail below.

Hearths with Seeds

All features containing more than 10 seeds per liter of sediment, or more than 40 charred seeds total, were placed in this category. The 17 features in this category range widely in size, between 0.3 and 2.5 meters in diameter, with an average of 1.2 m and a CV of 58%. The high CV indicates that there is no apparent preferred or optimal shape, again suggesting they may have been used to process a wide range of resources, or the same resources in a range of different volumes and stages of maturity (e.g., ripe vs. unripe). Fourteen (82%) have associated FCR, but none have recognizable toss zones or rock-lined bottoms. Granite is the dominant rock type in five features, with basalt dominant in another case.

Blazing star, ricegrass and chia seeds are most commonly associated with these features, being dominant in over 60% of the flotation samples. These species have been identified as staple foods in ethnographic descriptions (Fowler 1986; Steward 1933, 1938) and are very common in late prehistoric features throughout the region (e.g., Gilreath and King 2002). Millingstones are frequently associated with this feature type. At least 12 of the 17 features (71%) contain one or more fragments, supporting their interpretation as seed processing byproducts. Interestingly, glass beads are associated with at least four features (24%), demonstrating use into the early historic period.

Eight of the 17 (47%) lack or contain only low densities of burned faunal remains. However, quite unlike the formal pit-hearths, four (24%) contain moderate levels and five (29%) produced large numbers of burned bone. Rabbit (leporid) and unidentified small mammal were most common in these cases, though artiodactyl elements were also present. These remains suggest that this feature type was, at times, the byproduct of both animal and small-seed processing activities. Whether the floral and faunal remains were deposited as part of the same cooking event (i.e., stews), or represent re-use of an area (i.e., once for cooking seeds and once for cooking meat), is unknown. Unlike pit-hearths, it is clear that most of these features occur within the context of short-term habitation sites, which may account for their more generalized use.

Radiocarbon dates are available for 14 of the 17 features. Barring a single assay of 620 ± 50 BP, these dates are consistently younger than 270 BP. Indeed, eleven (79%) are younger than 200 BP. This suggests that this feature type is younger than the geophyte-processing pit-hearths discussed above. Because of their haphazard and informal construction, no "typical" illustration can be offered.

Hearths Lacking Seeds

This class includes the remaining informal features that lack large numbers of charred seeds. Of the 72 features in this class the vast majority (92%) contain significant amounts of FCR. Indeed, two-thirds contain only minimal charcoal suggesting most are little more than accumulations of FCR. These features range in size between 0.3 and 4.0 m (diameter) with an average of 1.3 m and a CV of 62%. There is no apparent modality in the diameters and the broad range and high CV indicates that they have little coherence in terms of size. In other words, there is no planning involved in the creation of these features, nor does use result in a consistent size.

For the 57 cases where investigators looked for bone, 38 (67%) lacked faunal remains, 14 (24%) had low quantities of bone, and five (9%) had moderate or high levels of bone. Leporid is the most common among the assemblages where bone is present. Thus, although they contain bone more often than the formal pit-hearths discussed earlier, on average they contain lower densities of bone than hearths with seeds. Groundstone is present in 22 cases (39%), ranging from a low of one item to a high of 16 pieces. These numbers are, again, slightly lower than hearths with seeds but, again, higher than formal pit-hearths. Wood charcoal is present in quantities greater than 1/2 gram per liter in 10 of 32 cases (31%), lower than both formal pit-hearths and hearths with seeds.

Together, the data from informal hearths lacking seeds indicate that these features may have been associated with more general non-seed-processing activities. The presence of significant FCR indicates that transferal of heat by way of indirect reservoirs was an important component of the cooking activities. The lack of identifiable subsistence remains in the majority prohibits identification of specific food resources.

Only 14 of the 72 have been dated by radiocarbon means. Dates from these features range between 0 (modern) and 3100 BP, with two falling in the Newberry Period (pre 1500 BP), six in the Haiwee Period (700-1500 BP), and six in the Marana to historic period (0-700 BP). In other words, these features date to all of the late prehistoric period, with no apparent clustering.

Interpretations and Significance for Regional Prehistory

Clearly, there is much variability among thermal features from this corner of the Mojave Desert. A range of different organic and inorganic remains were found, including animal bone, charred seeds, charcoal, FCR, and groundstone, indicating a range of uses. At the same time, it is also clear that this variability is patterned, both functionally and temporally. Table 1 summarizes the salient findings by feature type. Several patterns are considered in greater detail.

First, thermal features are predominantly a late prehistoric phenomenon. The oldest date is 3100 BP and only five (10%) produced dates older than 1000 BP. This pattern is not the result of a lack of investigation at older sites, as many early Holocene (ca. 9000 BP) through Newberry Period sites have been excavated. If thermal features are related to cooking activities, as we have argued, then cooking strategies were quite different after 3100 BP than before. In particular, the activities that led to the deposition of these types of features became increasingly more common after this date.

Second, and more specifically, there seem to be significant patterns in the age distribution of different feature types. In particular, pit features seem to date to the Newberry Period, pit-hearths to the Haiwee and early Marana Period, and informal hearths with charred seeds to the late Marana and early historic periods (i.e., the last 300 radiocarbon years). Informal hearths lacking charred seeds are more evenly distributed across the three time periods.

Table 1: Average attributes for different thermal features in the China Lake region.

Feature type	Total number	Average diameter meter (CV)	Main age range BP	Average number of charred seeds ^a	Average grams of charcoal ^a	Percentage with significant numbers of burned bone
Formal pits	6	0.8 (41%)	1450 - 3080	0.2	5.9	0%
Formal pit-hearths	38	0.9 (28%)	290 - 930	0.1	2.1	0%
Informal seed processing	17	1.2 (56%)	0 - 270	162	1.7	53%
Informal non-seed	72	1.3 (62%)	0 - 1890	0.2	1.1	9%
Informal unknown ^b	8	1.2 (43%)	180 - 690	N/A	N/A	0%
Total	141	1.16 (59%)	0 - 3080	25.1	1.9	11%

Notes: ^a - per liter of soil recovered in flotation studies.

^b Nine informal features did not have associated flotation samples to determine the quantity of charred seeds.

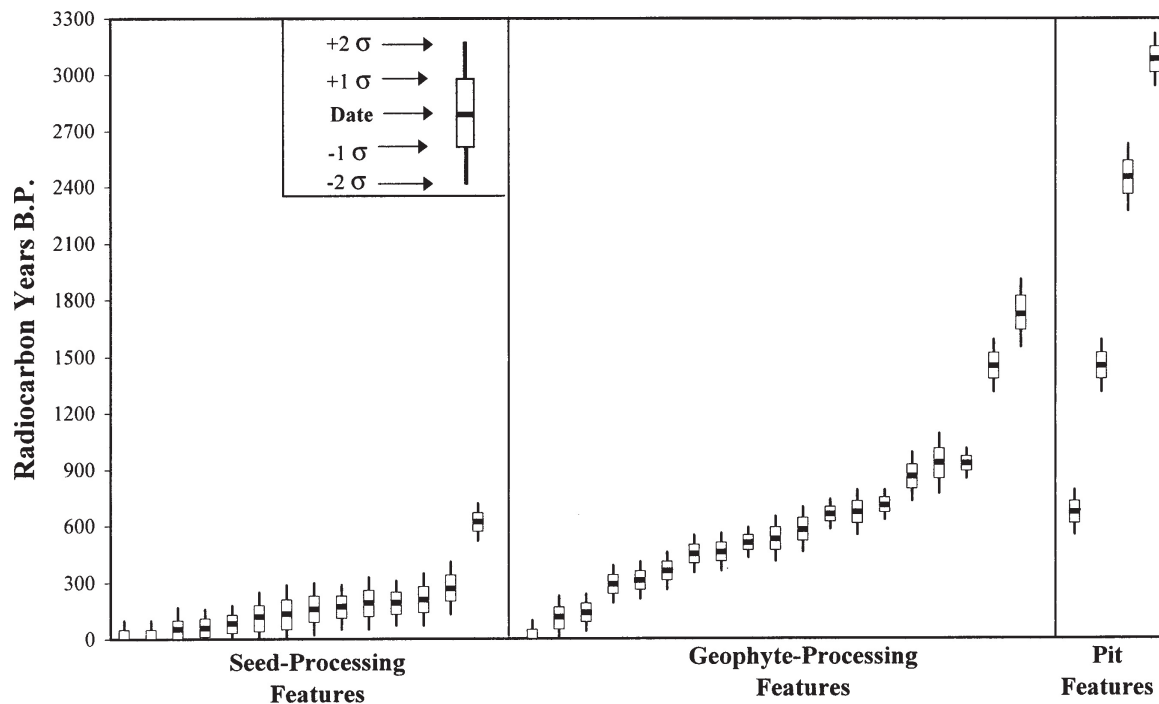


Fig. 4: Distribution of radiocarbon dates (uncorrected) for feature types.

Certainly this pattern is not without exceptions. For example, some pits date to the Haiwee (one of four), some pit-hearths are Newberry (two of 19) or late Marana in age (post 300 BP; three of 19), and some informal hearths with seeds are from the Haiwee Period (one of fourteen). These exceptions suggest that these temporal patterns are more a matter of degree than absolute and reflect different cooking emphases through time. Figure 4 graphs radiocarbon dates for the different features types.

Why is there a shift from the use of pits, between 3100 and 1400 BP, to geophyte processing in formal pit-hearths between 1000 and 300 BP, to seed processing in informal features after 300 radiocarbon years ago? Simple cultural preferences for thermal features of different shapes and sizes does not explain these trends. If earlier cultures preferred pit features and later groups preferred informal ones (for non-functional or historical reasons), we would expect to see mutually

exclusive ranges of dates for different feature types. The fact that some pits and pit-hearths date to later time periods and some seed processing features to earlier ones, suggests that functional reasons are at play. If different feature types represent different cooking activities, as we argue, then increases or decreases in the number of dates on various feature types reflect changes in the importance of these activities through time. In other words, although both seeds and geophytes contributed to the diet throughout all of the late prehistoric period, seeds were much more important late in time, after 300 BP, while geophytes were more important earlier, between 300-1000 BP.

What accounts for the change? We offer several potentially interrelated explanations. First, the difference could relate to environmental factors. In particular, the density of different plants may have changed at roughly 300 BP, making geophytes more attractive prior to this date and seeds more attractive after it. There is

some support for this hypothesis in paleoclimatic records from the region. Woodrat midden analyses from Coso Basin suggest there is a transition to slightly drier conditions around 300 BP (Wigand 2003). While the time period before 300 BP was not unilaterally wet, it appears to have been punctuated by episodes of increased rainfall (Brown, Hughes, Baisan, Swetnam, and Caprio 1992; Graumlich and Brubaker 1995; Scuderi 1987) that, among other things, led to an infilling of Mono Lake (Stine 1990). There is an uncanny correlation between these Mono Lake high stands and the radiocarbon dated pit-hearths from the northern Mojave Desert (Fig. 5). If greater regional precipitation led to an increase in the availability of geophytes, pit-hearths may reflect opportunistic exploitation of these resources. There is a further correlation between these wet periods and the frequency of wood rat middens in Coso Basin (Wigand 2003), indicating that wood rat populations were also responding to increased forage during wet intervals (Fig. 5).

While the environmental argument may explain the visibility of geophyte-processing features, it fails to account for why seed processing features are not more common during dry intervals prior to 300 BP (i.e., between transgressions in Fig. 5). Dry environmental

conditions similar to the last 300 years were in place between 680 and 605 BP and 550 and 465 BP, yet no rise in seed use is evident during those intervals. This suggests that the visibility of seed processing after 300 BP is largely due to other factors, such as population pressure, technological adaptations, and/or social processes.

Another possibility is that the shift from geophyte to seed processing is related to seasonal conflicts that either discouraged seed-processing earlier in time or geophyte harvesting later in time. Since geophytes are available in spring and seeds in summer, collection of these two resources is not mutually exclusive. Thus, a seasonal conflict must be found between some other activity and either geophyte or seed harvesting. By itself, this explanation is difficult to support, given that some seeds were harvested prior to 300 BP and some geophytes after this date. As well, ethnographic descriptions of subsistence in the Great Basin describe the heavy use of both geophytes and seeds (Fowler 1986, 1992; Steward 1933, 1938). Currently there are no archaeological data from the Northern Mojave that suggest people were on different parts of the landscape and/or involved in different activities before rather

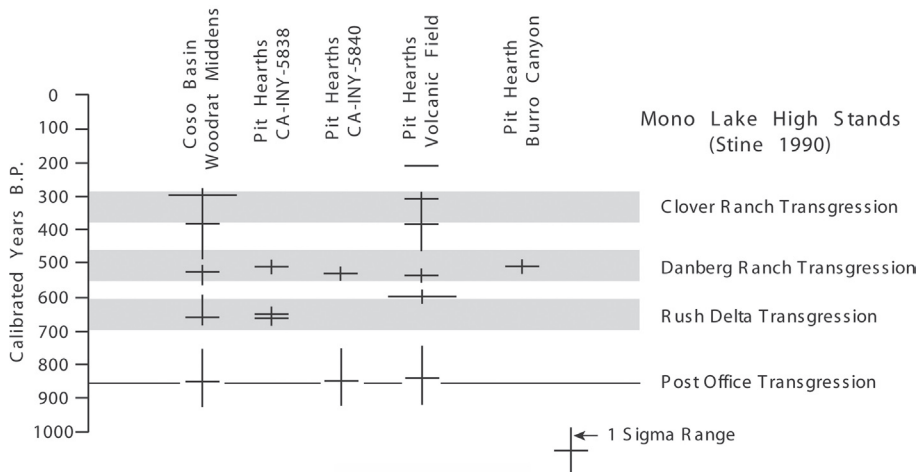


Fig. 5: Late Prehistoric ¹⁴C dates from pit-hearths and woodrat middens at China Lake.

than after 300 BP. Thus, seasonal conflicts do not appear to be responsible for the shift.

A third possibility, often invoked to explain culture change in the Great Basin, is population pressure. For example, following classical optimal foraging theory, an increase in the population base and a constricting of group territories around 300 BP may have forced people to widen their diet breadths to include lower-ranked resources such as seeds. The small size of seeds would have necessitated a large number of processing features to feed the increasing population, greatly increasing their archaeological visibility. However, if population pressure was a factor, it is hard to imagine that population size increased greatly within the Mojave Desert itself, given the arid and marginal nature of this region. More likely, populations increased on the edges of the Mojave, forcing people to occasionally move into and through places like Coso Basin when resources failed to provide enough outside it. Such groups would have had a material technology and social system already well-adapted to seed harvesting. Groups moving through Coso Basin were probably composed of small nuclear families and were highly mobile during the short window of time in which seeds ripened.

If population pressure on groups outside the Mojave was the driving force behind the shift to seed processing, it remains to be answered why we see a profusion of informal hearths only after 300 BP. There is good evidence from the nearby Owens Valley that intensive seed exploitation began at least 300, and possibly up to 1000, years earlier (Basgall and McGuire 1988; Bettinger 1975, 1989; Delacorte 1999). An earlier shift to seed-use also appears to have taken place in Death Valley (Hunt 1975; Wallace 1977) and the Central Valley (Wohlgemuth 1996). Presumably, populations had already expanded significantly in these other areas to bring about a focus on low-ranked resources like seeds by 1300-600 BP. It is possible that rising populations outside the Mojave slowly overexploited even seed

resources over several hundred years, requiring some people to disperse seasonally into other less densely occupied regions such as the Coso Basin after 300 BP.

A fourth possibility is that the shift to seed procurement after 300 BP was related to the technological innovations that changed the relative costs of geophytes and seeds. For example, the availability of ceramic pots may have made seeds a more worthwhile subsistence pursuit within the Northern Mojave. While people in the Western Great Basin were certainly aware of pottery earlier in time through contact with the Southwest and local experimentation (e.g., Eerkens, Neff, and Glascock 1999), it may have taken a long time to modify the technology to suit the demands of a mobile lifestyle. For example, it has been established that pottery from the Northern Mojave is significantly thinner and displays a different temper recipe than pottery in other areas (Eerkens 2001). Thinner pots are lighter in weight, dry quicker, and transfer heat more efficiently than thicker ones, but are less resistant to impact shock and break easily (Bettinger, Madsen and Elston 1994:95; Braun 1983; Juhl 1995). It may have taken much experimentation to find the right clay and temper recipe to mitigate the loss of strength resulting from thinner walls (Bronitsky and Hamer 1986; Eerkens 2003a). Similarly, changes in millings in the late prehistoric period towards a more portable technology (Bettinger 1989:206; Delacorte 1999:272) also may have affected the relative costs of seed versus geophyte processing. Once this more portable cooking and milling technology was available the associated costs of seed harvesting may have been lowered to make these resources more attractive in the Northern Mojave.

Finally, social conditions also may have favored the collection and processing of one resource over another. For example, a desire to harvest more storable foods may have prompted a switch to seed use. As Bettinger (1999) has argued, a refocus within the diet on such resources may be an outgrowth of changes in

resource ownership strategies, that is, from a public-goods system to a privatized one. Again, with this argument it remains to be explained why a desire for more storable products took hold only after 300 BP. Perhaps people sought to buffer against the more variable and drier climate that was in place after 300 BP.

Most likely, climate, population pressure, technology, and social factors fed off of one another in a complex feedback cycle to produce the archaeological patterns observed. Thus, increases in population and slight changes in the availability of different resources due to climate may have prompted changes in harvesting and processing technologies. Changes in technology then may have provoked changes in the desirability of different resources for social reasons. More storable resources may have evened out resource shortfall in lean seasons, thereby increasing population levels. Moreover, increased harvesting and consumption of seed resources may have served to spread seeds, and consequently seed-bearing plants, over larger areas. This spreading may have made seed resources more widely available and more attractive to consumers.

The location and context of the different features is also interesting. As mentioned, while most of the seed-processing features are found within the context of sites containing midden and other domestic refuse (i.e., short-term base camps), pit-hearths are often isolated from other artifacts, though they are often found in clusters. This observation suggests that geophytes are frequently collected and processed as part of isolated gathering events conducted away from living quarters. This result is in line with that reached by Thoms (1989: 290-291) for the development of economies focused on geophytes in general. He suggests that in order to minimize transport costs, geophytes are usually processed within short distances of (i.e., no more than 10 km from), but distinctly outside of, base camps. However, this finding contrasts with ethnographic descriptions offered by Fowler (1992:81) for the Northern Paiute around Stillwater Marsh, where

fresh roots and bulbs were carried back to a base camp and cooked in pit-hearths.

On the other hand, given the archaeological evidence currently available, it appears that seeds were primarily processed within domestic contexts. We recognize that part of this pattern may result from the difficulty in recognizing isolated informal thermal features archaeologically. If present, such features, especially those lacking significant quantities of FCR, may appear to be the remains of natural burns rather than the byproducts of prehistoric cultural activities and may be overlooked during archaeological survey.

Finally, although beyond the focus of this paper, the results obtained here may also bear on the concept of the "Numic Expansion" as conceived by Lamb in 1958 and hotly debated since by many archaeologists (Ambler and Sutton 1989; Bettinger and Baumhoff 1982, 1983; Kaestle and Smith 2001; Madsen and Rhode 1994; Sutton 1986, 1993, 1994; Young and Bettinger 1992). If Numic populations are marked in the archaeological record by intensive extraction of food resources (e.g., Bettinger and Baumhoff 1982, 1983), especially small seeds, our results suggest that Numic populations did not expand into and make use of the China Lake region until very late in prehistory, roughly 300 radiocarbon years ago. This is much later than would be predicted if the Mojave Desert was the original homeland of the Numa before they expanded outward to the Northeast (e.g., Sutton 1993, 1994). As mentioned above, intensive seed use is documented significantly earlier than 300 B.P. in other regions of the Great Basin, such as the Owens Valley. Additional research is clearly necessary to resolve this issue.

Conclusions

Analyses of thermal features from the Northwestern Mojave Desert demonstrate a shift from formal pit construction prior to 1500 BP, to formal pit-hearth construction between 1000 and 300 BP, to the use of

informal hearths containing seeds after 300 BP. Other informal hearths lacking seeds date to all three periods. These changes are more a matter of degree than absolute, as small numbers of pit-hearths date after 300 BP and small numbers of informal hearths with seeds date before 300 BP. We argue that these changes reflect differing foci of subsistence pursuits in the region, with pit-hearths used for geophyte processing and informal hearths for processing seeds and small mammal remains. Because of a small sample size, the function of the earlier pit features remains unclear, although they too may have been used for geophyte roasting.

It remains to be seen how applicable these patterns are when extrapolated outside the northwest Mojave Desert. For example, there is good evidence from the Owens Valley that intensive seed exploitation began at least 300, and possibly up to 1000, years earlier (Basgall and McGuire 1988; Bettinger 1975, 1989; Delacorte 1999; Eerkens 2001). On the other hand, although much more limited in extent (i.e., only a small number of flotation samples have been analyzed), seed processing in the Fort Irwin area appears to be associated only with radiocarbon dates 250 years and younger as well (Basgall 1993; Basgall, Hall and Hildebrandt 1988; Hall 1992). To our knowledge, formal pit-hearths similar to those discussed above have not been recorded in either Owens Valley or Fort Irwin, suggesting that geophyte processing may never have been an important economic pursuit in these locations.

Thus, while intensive seed processing develops across all of the western Great Basin in the late prehistoric period, intensive bulb processing appears to be a more local phenomenon. In the northern Mojave, bulb processing appears to be a supplemental subsistence pursuit in a supplemental and sparsely occupied region. All of this suggests that different regions of the Great Basin and Mojave Desert need to be evaluated independently regarding shifts in dietary focus, intensification,

and technological adaptations, particularly with regards to the timing and reasons behind these shifts.

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