Human Ecology, Vol. 29, No. 4, 2001

Pithouse Architecture and the Economics of Household Formation in the Prehistoric American Southwest

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Changes in prehistoric Southwestern architecture have been interpreted as the result of increasing dependence on agriculture through time which promoted greater sedentism. Recent archaeological research has produced data that point to changes in labor organization rather than agricultural productivity as the factors that most likely favored new forms of domestic architecture. In fact, some of the most striking temporal shifts in residential architecture may have been associated with declining agricultural productivity.

KEY WORDS: American Southwest; pithouses; intensification; households.

ARCHITECTURAL CHANGE AND AGRICULTURAL INTENSIFICATION

Among archaeologists of the American Southwest there is a widespread view that prehistoric vernacular architecture was closely linked to subsistence economies, especially the degree to which an economic system allowed long-term group sedentism; protracted sedentism is assumed to produce greater investment in housing and other permanent facilities, as well as more functionally specific activity areas (e.g., Plog, 1973). Pit structures are poorly suited to the expansion of habitation space compared to surface rooms (Schiffer and McGuire, 1992) and therefore situations in which settlement *growth* is necessary or anticipated should favor alternatives to pithouses. This assumption has been particularly important in efforts to explain

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the replacement of pit structure dwellings by contiguous blocks of surface rooms, a development referred to as the "pithouse-to-pueblo transition" in the Southwest, but which is clearly an example of more general patterns of settlement change in arid regions throughout the world (Byrd, 1994).

Gilman (1987) compiled an extensive array of ethnographic data about societies that build pit structure dwellings and observed that pithouses are generally used by groups that depend on stored food to support extended seasonal periods of residential immobility. She used this ethnographic relationship to argue that the pithouse-to-pueblo transition was likely an accommodation to greater storage needs and specialized food processing stemming from intensification of agricultural production (Gilman, 1987, p. 548; see also Hunter-Anderson, 1977).

Gilman's proposition is generally attractive, and has been very influential, simply because farmers have to increase storage capacity in order to realize any long-term value from higher yields and therefore energy investment in storage architecture would likely signal a corresponding increase in storable produce (see Flannery, 1972). However, Gilman did not identify any particular *per capita* consumption rates or exact levels of productivity that would make the costs of pithouse architecture unacceptable, and she equates agricultural intensification with greater amounts of stored food rather than increases in the amount of labor per unit of marginal return (Gilman, 1987, p. 554). While the model highlights a significant relationship between spatial complexity and sedentism, the role of agricultural intensification is not clear-cut.

In defense of Gilman's model, the archaeological record does indicate that the expansion of storage capacity within pit structures was limited by the constraints of subterranean building methods, and that efforts to increase storage by appending new pit structures were not particularly efficient. However, we cannot use potential food storage capacity as a proxy for agricultural intensification as that creates a circular logic. To determine whether the need for more storage space and greater spatial functionalization was driven by increased agricultural productivity, we have to have lines for evidence for evaluating food production that are independent of architectural patterns.

I think the first step in such an evaluation should be to separate the issue of storage capacity from the concept of economic intensification. Large crop yields or high levels of domesticate consumption might be the product of intensification, but not necessarily. In economic theory, intensification usually refers to decreasing marginal returns per unit of input; for example, when an increase in the amount of labor in a production process leads to a decline in the average per capita productivity. Overall yield might still increase but the process could be experiencing diminishing returns or yields could increase rapidly without any significant intensification if the marginal returns to labor were high. Diminishing returns are the hallmark of intensification in tribal economies (Eder, 1991; Flannery, 1972; Netting, 1990; Sahlins, 1972). Thus the size of a crop is not a direct indicator of intensification, and increases in storage volume or spatial specialization alone are inadequate archaeological measures of changes in economic production.

Therefore in order to assess the proposition that changes in pithouse architecture (including cessation) were caused by economic intensification, we need to demonstrate that labor allocations to associated production strategies increased as well. We can approach this problem through at least two aspects of prehistoric economies likely to have had material consequences: (1) diet composition and (2) the technology associated with food production and consumption. Dietary indicators of intensification would primarily involve a shift to greater use of resources that provide lower returns for the effort required to obtain them. Technological indicators of intensification would include developments in tools that reflect more time and/or energy per unit of return, or greater functional specialization (Nelson, 1991). If Gilman's model for the replacement of pithouses is generally applicable, then it should explain changes in pithouse variability before the pueblo transition as well.

In the remainder of this paper I consider temporal changes in pithouse architecture and associated evidence for agricultural intensification throughout the Southwest. Although maize agriculture was introduced to the region by at least 1500 B.C., significant changes in pithouse size and complexity did not occur until ca. A.D. 1–500, when pit structures became much larger with clear indications of functional specialization in interior space. This shift corresponds to the appearance of ceramic containers as a critical food processing technology, as well as other indicators of labor intensification. I conclude that these changes in architecture were not the result of increased agricultural surplus or dietary dependence, but rather a significant intensification of female labor in food processing associated with the emergence of relatively autonomous households as the fundamental unit of production and consumption. Subsequent reversals in pit structure size probably indicate the incorporation of households into larger social networks in which household economic independence was more restricted.

VARIABILITY IN PITHOUSE ARCHITECTURE

Southwestern archaeologists have always recognized differences in the size and formal characteristics of pithouses and early on used this variability to create culture histories for particular geographic areas (Hough, 1919; Martin *et al.*, 1949; Nesbitt, 1938; Roberts, 1939; Wheat, 1955). Many of these formal distinctions in pithouse architecture retain their original clarity and are still widely used as temporal markers (e.g., Anyon *et al.*, 1981; McKenna and Truell, 1986). Nevertheless, until recently there has been considerable willingness among researchers to lump all pithouses into a single category or class, especially when discussing issues of sociocultural change (see Cordell, 1997). While pit structures may reasonably be treated as a discrete kind of architectural form, the considerable synchronic and diachronic variability in the size, configuration, and construction of structures that archaeologists call "pithouses" surely makes this a classification of only limited interest.

For example, when sites include multiple pit structures, the likelihood of significant physical differences between structures is very good, regardless of time period, and consequently this relationship is a candidate for sample size effects. An illustration of large sample variability is evident in recent investigations of preceramic pithouse settlements in the Santa Cruz Valley outside Tucson reported by Gregory and Huckell (1998); also Huckell, 1995, where there is a striking dichotomy between houses with large storage pits and those without. Researchers feel confident that at least three functional types of pit structures existed during the Early Cinega phase (800–400 B.C.), those that had exclusive storage functions, those used primarily for habitation, and those in which food processing and storage were combined. A fourth type—the communal or "public" house—is also possible based on the presence of a few unusually large structures (Mabry, 1998, p. 240).

The first systematic excavations of pithouse settlements in the Southwest encountered exceptionally large structures that archaeologists assumed to have had ceremonial, ritual, or other communal functions (Haury, 1940; Hough, 1919; Martin, 1943; Roberts, 1929) and so the perception of a dichotomy between small domestic dwellings and larger nonresidential structures has always been a prominent component of pithouse culture history. It is the identification of *functional* variation between residential or domestic pit structures that distinguishes recent fieldwork, such as Schmader's study of pit structures on the western terraces of the Rio Grande near Albuquerque dating between A.D. 550 and 900 (Schmader, 1994). Schmader suggests that small, shallow structures with well-constructed central firepits were used for food preparation and contemporaneous large, deep structures were for sleeping and other domestic activities. Other examples of intrasite functional differentiation among pit structures from the ceramic period include small grinding rooms (Nichols and Smiley, 1984; Mobley-Tanaka, 1997), possible sweat lodges and mortuary facilities (Wills, 1996), and menstrual huts (Crown, 1985).

These inferences suggest that even during the preceramic period (prior to A.D. 200), pit structures were used for a range of activities and therefore we cannot assume a priori that a "pithouse" was indeed a house. Pit structures exhibit progressively greater variability and complexity through the ceramic period of Southwestern prehistory, a trend that warns us to avoid any simple equivalency between pit structures and habitation dwellings (see especially Gilman, 1987; Schlanger, 1998). Likewise, we should be cautious of any simple correlation between population estimates and the number of pit structures on a site if functionality has not been considered first.

Diachronic variability in pithouse architecture is also more complicated than traditional culture historical reconstructions indicate, a fact that has been especially well-established by researchers in the southern Rio Grande Valley. For example, Whalen's long-term study (Whalen, 1981, 1994a,b) of human adaptation in the Jornada region of the southern Rio Grande Valley demonstrated that pithouse size increased through time even though settlement systems remained relatively stable. Preceramic Jornada pithouses were quite small, but cluster in two distinct size modes, small houses averaging about 3.8 m^2 in floor area and larger houses averaging about 6.0 m^2 (Whalen, 1994b, p. 627). Large pre-ceramic houses tend to occur in river valleys and are interpreted as winter aggregation settlements, while smaller structures are seen as the remains of much shorter occupations by small groups engaged in spring or summer foraging. Later ceramic period (Mesilla phase, A.D. 750–1100) pithouses also form two size modes, at 5.0 and 11.8 m^2 again interpreted as the product of short-term foraging and extended winter aggregations respectively. Whalen (1994b, pp. 632–633) attributes the increase in size to more complex site structure, especially the addition of storage features. Mauldin (1995) also analyzed Jornada settlement patterns, although with a larger data set than Whalen, but he too noted approximately the same pit structure size dichotomies. However, Mauldin proposed that small pithouses were used during winter months and large pithouses were associated with summer agricultural settlements.

An important study of pithouse variability by Stuart and Farwell (1983) suggested that the depth—and hence volume—of late ceramic period pithouses in higher elevations in the Southwest (above 1500 m) was at least partially a function of thermal efficiency associated with very cold winter habitations. Rocek (1998) revisited the Stuart–Farwell hypothesis with a new set of data, including the Jornada settlement data noted above, and verified the observation that the size of Mogollon pithouses (both depth and floor area) covaries significantly with elevation, suggesting a very strong environmental control on pithouse size. However, Rocek's analysis also indicates that there are intriguing differences between lowland and highland pithouses in size through time that must be related to factors other than climate. For example, although highland and lowland pithouses are extremely different in size during the early ceramic period, median floor area converges after about A.D. 700 (Fig. 1).

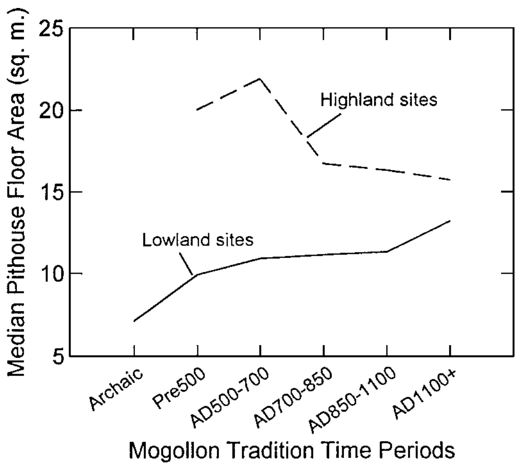

Fig. 1. Temporal trends in floor area (square meters) for pithouses in south-central New Mexico. Lowland sites are below 1500-m elevation. "Mogollon Tradition" refers to the culture historical classification for this region. Data from Rocek (1998).

On the basis of these and other recent pithouse studies, there appear to have been at least two diachronic "episodes" involving marked dimensional change in pit structures. First, it is overwhelmingly apparent that throughout the Southwest preceramic pithouses were smaller than later ceramic period pithouses. Within the preceramic period, pithouses lacking evidence for associated maize cultivation are nearly always smaller (typically about 5 m^2) than pithouses associated with maize remains (typically about 10 m^2), whether the comparison is intrasite, as in the Santa Cruz Valley in southern Arizona (Gregory and Huckell, 1998) or intraregional, as in the Jornada region (Whalen, 1994a,b). Preceramic pithouses date to at least 5000 B.P. in the Southwest (Wills, 1994), which means that their consistent small size is one of the most conservative material patterns in Southwestern prehistory.

In contrast, dramatic increases in pithouse size occurred at the beginning of the ceramic period. This relationship is extremely well-documented in southern Arizona, where early ceramic pithouses average nearly three times the floor area of preceramic pithouses, although the most rapid *rate* of increase was between the early ceramic period Plain Ware (A.D. 150–550) and Red Ware (A.D. 550–700) horizons, a shift from 10 to 19 m^2 (Mabry, 1998, p. 219). Elsewhere, early ceramic period pithouses were frequently many times larger than antecedent preceramic pit structures, as, for example, in west-central New Mexico, where Pine Lawn Phase (ca. A.D. 350–550) pithouses are more than five times as large as late preceramic pithouses (Wills, 1996), a pattern similar to the one documented by Rocek (1998) for the highlands in south-central New Mexico. The exact magnitude of this size increase across the ceramic temporal boundary is variable subregionally, but appears to have typically involved at least a doubling of pithouse floor area. A possible exception to this temporal pattern of pithouse size increase in the early ceramic period is the Durango area of southwestern Colorado where late preceramic (ca. A.D. 200–400) pithouses excavated by Morris and Burgh (1954) were extremely large, including some in excess of 50 m^2, and built with massive timber superstructures. Nonetheless, since these large Durango preceramic pithouses precede the introduction of pottery by a few generations at most (Blinman and Wilson, 1993), or may even have been contemporaneous, they were closely associated in time with this technological development. Overall, the preceramic-to-ceramic transition in the Southwest, which varies between ca. A.D. 1 and 500 in most subregions, marks a major increase in pithouse size and it must be significant that this relationship is evident in different cultural traditions and geographic regions.

A widespread but less striking change in pithouse size is a diminution in floor area after about A.D. 900 in subregions where early ceramic period houses were quite large (Doyel, 1991, p. 243; Gilman, 1987; Schlanger, 1987). With the exception of southern Arizona, these shifts to smaller domestic pit structure size clearly covaried with increasing investment in surface architecture, or the "pithouse-to-pueblo transition."

In summary, preceramic period pit structure use was astonishingly static with respect to floor area, despite the evidence for functional variability, suggesting that controls on structure size—whatever they might have been—were equally stable. The introduction of maize agriculture does seem to have produced a need for storage facilities, but there is no evidence that the use of domesticated plants lead to any major change in the size of domestic dwellings during the preceramic period. By contrast, pithouse size and construction at the ceramic temporal boundary reflects an explosion in variability that included size, formal features, and functional specialization; the suddenness of this change compared to the preceding millennia of stability suggests some sort of threshold phenomenon. Similarly, the decline in pithouse size associated with the adoption of pueblo architecture took place in a context of a striking increase in the overall architectural complexity of individual settlements. Following Gilman's model, we should expect that these two changes in settlement complexity involving pit structures were related in some systemic with economic intensification. In the next two sections I will attempt to determine whether this anticipated relationship exists.

DIETARY INDICATORS OF SUBSISTENCE INTENSIFICATION

Efforts to reconstruct pithouse period diets have been disappointing, especially with respect to estimating maize contributions. A currently popular method for diet reconstruction in the Southwest is the calculation of "ubiquity" measures based on the presence of plant or animal taxa in various kinds of samples (Popper, 1988, p. 61). Ubiquity scores primarily indicate relative importance of taxa rather than their absolute dietary contribution and therefore cannot be interpreted as equivalent to the proportion of a taxon within a prehistoric diet (see Huckell, 1998, p. 142). Nonetheless, maize ubiquity is widely viewed in the Southwest as indicative of varying amounts of agricultural "reliance." Rocek (1996) surveyed many of these studies and concluded that a broad range of preservation and sampling problems confound any simple extrapolation between sample ubiquity and the proportional contribution of maize (or other cultigens) to prehistoric diets. Presence/absence data are potentially informative, but not in any straightforward or consistent manner (see also Hard *et al.*, 1996).

For example, maize ubiquity is often higher in preceramic sites than in later ceramic pithouse settlements. Maize ubiquity in preceramic sites around Tucson ranges from 84 to 100% of flotation samples (Huckell, 1998), figures that are higher than those obtained from later Hohokam ceramic sites associated with massive irrigation systems and centralized grain storage (Fish *et al.*, 1990). Temporal trends can be confusing even within the same study (Figs. 2 and 3). I suspect these various temporal patterns in maize macrofossil ubiquity indicate that this particular measure does not accurately predict the *intensity of agricultural production*, since relatively small, short-term preceramic sites frequently score higher than large, high population density villages associated with large-scale water control systems and extensive storage facilities. Likewise, ubiquity scores cannot be reliably extrapolated to contemporaneous sites in the same region, as seen in data from the southern Arizona preceramic agricultural period, where high maize ubiquity figures found in the Santa Cruz River sites in the Tucson Basin contrast with the complete absence of maize in similar contemporaneous sites in the same drainage system or in neighboring drainages (Gilman, 1998; Henderson, 1993).

I suggest that what is most pertinent about the current record of maize ubiquity measures is that the likelihood of high scores (60–100%) is good in nearly *any site postdating the initial introduction of maize to the Southwest in which maize is present*. Variability in scores appears to be higher among preceramic agricultural sites than later ceramic period sites,

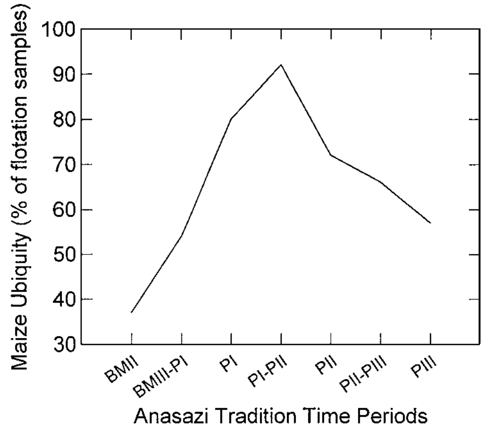

Fig. 2. Temporal trends in maize ubiquity (% of *flotation* samples) for excavated sites by time period in the San Juan Basin, northwest New Mexico. "Anasazi" refers to the cultural historical classification for this region; BMII (ca. 800 B.C. to A.D. 400) is preceramic, BMIII (ca. A.D. 400–750) is early ceramic. Data are from the ENRON Project, Office of Contract Archaeology, University of New Mexico (Hammet and McBride, 1993).

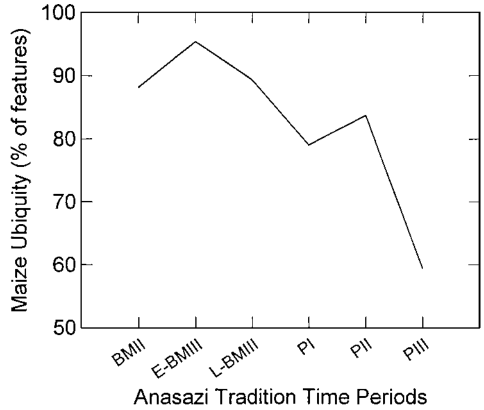

Fig. 3. Temporal trends in maize ubiquity (% of *features*) for excavated sites by time period in the San Juan Basin, northwest New Mexico. Data are from the EPNGSE Project, Western Cultural Resoruce Management, Inc., Farmington, New Mexico (Kearns and McVickar, 1996).

but almost any ceramic period site with maize present is likely to show at least 60% maize ubiquity in samples, whether calculated by flotation, site features, or other units. I think that the trend in many regions toward lower maize ubiquity scores in the later ceramic periods compared to the preceramic and early ceramic periods is more closely linked to site complexity than to dietary importance. Plog and Hegmon (1993) point out that sample comparisons are strongly affected by the diversity of features found on a site, and so it might be misleading to compare total numbers of flotation samples from two settlements if they differ greatly in the nature of structures and other features. Diehl (1998) makes a similar argument and is probably correct in assuming that preceramic agricultural sites were less heterogeneous with respect to habitation features than later Hohokam villages, and hence similar maize ubiquity measures do not likely reflect similar kinds of agricultural economies. However, the issue is not exactly heterogeneity but the fact that as settlements became larger and activities were more spatially discrete, more parts of a site might be isolated from food processing activities (Crown, 1999) and therefore a representative archaeological sampling scheme would produce more samples lacking maize and hence lower ubiquity scores; ironically, it might be a *decline* in maize ubiquity that supports Gilman's intensification model (Gilman, 1987). This should be a systematic behavioral relationship rather than a temporal one, in that any change in site structure that removes some space from contact with food processing or storage could be expected to reduce ubiquity scores. In this light, the explanatory significance of ubiquity scores for *maize dependence* (as opposed to other issues, such as dietary diversity) is probably nil.

In contrast to the problematic approach of identifying intensification from recovered plant remains, we might hope for better resolution from a more direct analytic approach such as bone chemistry. For instance, Chisholm and Matson (1994) asserted that isotopic analysis of human bone from the Colorado Plateaus provides good evidence that maize comprised 70–80% of late preceramic diets based on δ^{13}C values ranging between −14.1 and −12.0 from samples dating between A.D. 200 and 400. Unfortunately, it is impossible to use these isotopic data to accurately infer the proportion of maize contribution to prehistoric diet because maize was not the only C4 plant consumed by southwestern agriculturalists. In fact, human skeletons from the Southwest exhibit isotopic values indicating diets with up to 40% or more consumption of C4 plants prior to the adoption of maize. These issues have been outlined in detail elsewhere (Wills, 1992, 1994; Wills and Huckell, 1994), and are synthesized by Hard *et al.* (1996), who argue that while the dietary effect of maize is evident by at least A.D. 200 in the Colorado

Plateaus, the exact dietary contribution from maize cannot be determined from isotopic values.[2]

Still, isotopic data do tell us something very important about prehistoric diets at a general level that is relevant to the issue of economic intensification rather than maize consumption per se. The large contribution of C4 plants in preagricultural diets reflects input from plants and small animals that offer relative low return rates to foragers. At least 2000 years before the adoption of maize, forager populations were devoting considerable effort to resources with high handling costs, especially small seed plants such as chenopodium, amaranth, saltbush, and grasses (Simms, 1987; Toll, 1983). Even after the appearance of maize, these low-return plants continued to be consistent components of archaeological plant assemblages. Rank-order measures for economic plant taxa (measured as ubiquity[3]) from several portions of the Southwest suggest that diets changed very little between the preceramic and ceramic periods, or during the transition to puebloan architecture. In select samples from both southern Arizona (Fig. 4) and the Colorado Plateaus (Fig. 5) there is no significant difference in taxa ranks between the end of the preceramic and the beginning of the ceramic. Minnis (1989) observed a similar lack of change in plant taxa from human coprolites in the Mesa Verde area spanning the entire ceramic period sequence, a pattern that is also evident in flotation samples from recent excavations in the San Juan Basin (Fig. 6). Not only do maize and wild small-seed plants dominate plant assemblages before and after major changes in pithouse architecture, but the specific high-ranked plants from extremely different environments are remarkably similar. In other words, although there are obviously some dietary differences attributable to habitat variability (such as hedgehog cactus in Arizona), for the most part farmers throughout the Southwest seem to have been focused on the same basic set of domesticated and wild plant foods, most of which involved labor-intensive collection and processing. The persistence of small, hard seeds in Southwestern diets throughout the agricultural period indicates agricultural productivity was never sufficient to reduce the importance of these wild resources, despite their labor-intensive processing costs (see Wright, 1994).

Similar observations can be made for animal procurement. Some archaeological faunal assemblages exhibit variability due to local habitat features (for example, bison in the eastern Southwest) but for the most part

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[2] We should especially avoid the extrapolation of dietary inferences *backwards* into time periods for which there are no isotopic data (e.g., Chisholm and Matson, 1994). That is, unless dietary data reflect the full temporal range of phase or period (and geographical range for that matter), we cannot assume that earlier portions of such a historical unit would produce the same isotopic signatures. This seems obvious, but many researchers in the Southwest have argued otherwise.

[3] Although I suggested that ubiquity was not a good measure of the exact proportion of maize in a diet, I do think that ubiquity offers a useful method for comparing different diets.

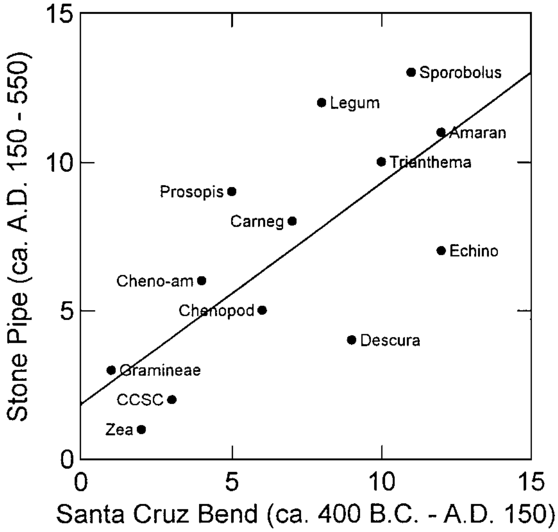

Fig. 4. Rank-order correlation of economic plant taxa from the Santa Cruz Bend site (preceramic) and the Stone Pipe site (early ceramic), Tucson Basin, Arizona ($r = .720$; $\chi^2 = 7.674$, df = 1; prob = .006). Key: Zea – maize; CCSC – columnar-celled seed coat fragments, source plant unknown; Gramineae – grasses, Chenopod – chenopodium; Cheno-am – chenopodium or amaranth; Carneg – saquaro cactus; Descura – tansy mustard; Prosopis – mesquite; Echino – hedgehog cactus; Trianthema – purslane; Legum – tepary bean; Amaran – amaranth; Sporobolus – sand dropseed. Data from Huckell (1998).

there is tremendous consistency through time in hunted species, with lagomorphs and artidactyls dominating in all time periods (Spielman and Angstadt-Leto, 1996; Szuter and Bayham, 1989). However, in some cases researchers have argued that increasing sedentism (especially during ceramic periods) resulted in rapid local depletion of large game, thereby increasing the distance to prey and raising the pursuit and transport costs of hunting, which in turn promoted selective hunting of high-return species such as deer (Bayham, 1982; Speth and Scott, 1989). Resource depression as a product of sedentism and population aggregation is a prominent component of intensification models (e.g., Kohler and Van West, 1996) and it is almost certain that local prey densities would have fallen quickly in areas where sedentary communities were developing. Much of the variability evident in faunal assemblages from prolonged occupational sequences appears to have been produced by such short-term processes, rather than fundamental changes in diet (e.g., Stratton, 1999).

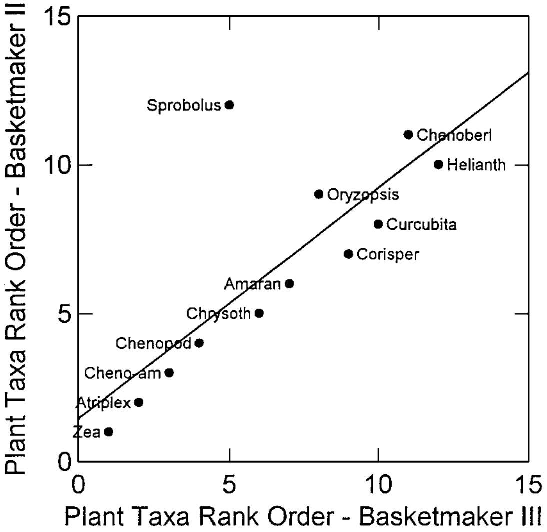

Fig. 5. Rank-order correlation of economic plant taxa from Basketmaker II (preceramic, ca. 400 B.C. to A.D. 400) and Basketmaker III (early ceramic, ca. A.D. 400–750) from excavated sites in the San Juan Basin, northwest New Mexico ($r = .776$, $\chi^2 = 8.765$, df = 1; prob = .003). Key: Zea – maize; Atriplex – fourwing saltbush; Cheno-am – chenopodium or amaranth; Chrysoth – rabbitbush; Amaran – amaranth; Corisper – *Corispermum*; Oryzopsis – ricegrass; Sporobolus – sand dropseed; Chenoberl – *Chenopodium berlandieri*; Helianthus – sunflower. Data from Kearns and McVickar (1996).

This is an extremely cursory sketch of dietary reconstruction for pithouse periods, but I am convinced that there are enough data to indicate that our presumptions about what the archaeological record *ought* to demonstrate about subsistence may be very far off the mark. We assume that greater sedentism and energy investment in architecture must arise from a highly productive agricultural system that permits long-term occupational stability, and therefore we also assume that greater sedentism will covary with changes in food production that in turn can be monitored through various conventional sources of information derived from the actual food remains. Instead, the empirical record fails to reveal much variation through time in diet. Some researchers have concluded that these patterns (especially light isotope data) denote levels of agricultural dependence in the late preceramic period similar to those at the end of the prehistoric period (e.g., Matson and Dohm, 1994). This may be true, but logically we cannot draw such a conclusion from these data because diet is not the same as food production and a

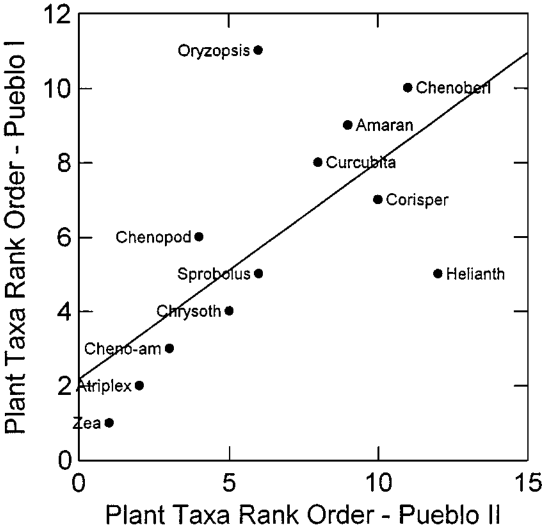

Fig. 6. Rank-order correlation of economic plant taxa from Pueblo I (ca. A.D. 750–920) and Pueblo II (ca. A.D. 920–1140) sites in the San Juan Basin, northwest New Mexico ($r = .663$, $\chi^2 = 5.491$; df = 1; prob = .019). Key same as Fig. 5. Data from Kearns and McVickar (1996).

stable diet is not necessarily a reflection of a stable economy. We still need to consider the role of labor.

TECHNOLOGICAL INDICATORS OF SUBSISTENCE INTENSIFICATION

A variety of recent studies indicate that the adoption of ceramic technology in the Southwest was associated with a complex set of changes in food processing that reflect greater time investment, especially for women. For example, Hard (1990) and Mauldin (1993) have argued that the amount of grinding surface area on milling stones can be used to estimate reliance on maize agriculture by assuming grinding time to be a proxy measure of dietary dependence. Grinding is a tremendously inefficient process in terms of energy consumption (most is lost to heat) and therefore larger grinding stones are designed primarily to increase the amount of grain milled per unit of time at great energy cost (Hard, 1990, pp. 137–138). In a survey of several subregions in the Southwest, mano (handstone) surface area increased steadily through time and across the ceramic boundary (Fig. 7), but the rate

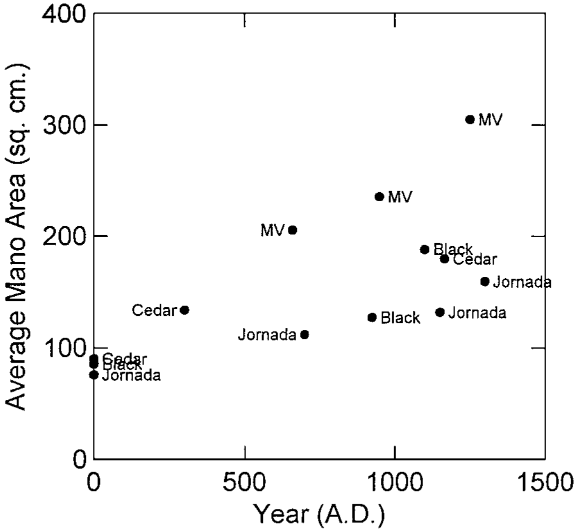

Fig. 7. Temporal patterns in average mano surface area (square centimeters) for various localities. Key: Black – Black Mesa (NE Arizona), Cedar – Cedar Mesa (SE Utah), Jornada – south-central New Mexico, MV – Mesa Verde (SW Colorado).

of change shifted upward dramatically after about 1000 A.D. (Hard *et al.*, 1996, pp. 292, 297). Other studies have also demonstrated gradual increases in milling stone size from the late preceramic through the ceramic periods (e.g., Adams, 1998). In addition to increases in surface area, the early ceramic period marks an increase in functional specialization among grinding tools, with the addition of rectangular manos and trough metates (Wills, 1996), a change that involved a more fatiguing stroke motion compared to the rotary grinding characteristic of small round preceramic period handstones (Adams, 1993, 1998; Morris, 1990). Whether these data mean that dietary input from maize increased through time is unclear, but they certainly indicate that milling technology changed in ways consistent with greater time allocation to grain processing and higher energy costs.

The increased emphasis or reducing grain to flour fits with one of the primary functional advantages found in pottery, the ability to cook porridge or stews by slow, direct application of heat. Slow boiling or simmering increases the range of food preparation options and significantly enhances the nutritional value of many foods (Arnold, 1985). Long-term boiling helps remove fiber, concentrates the carbohydrate fraction of maize, and slows digestion, thereby promoting greater nutrient absorption (Stahl, 1989, p. 177; Wandsnider, 1997). Grinding seeds to flour accomplishes a similar range of functions, especially improving digestibility (Wright, 1994). Pottery provided the critical technology for increasing *nutritional* yield independently of any necessary change in the amount of cultivated foods available or the size of crop yields.

It seems clear that the adoption of ceramics and increased size and complexity of milling tools were part of labor intensification. Ethnographic studies reveal that preparing dried maize for cooking is a laborious and time-consuming process; in maize-dependent agricultural societies, women typically spend many hours daily grinding flour. For example, Schiffer (1975) outlined at least seven maize processing tasks performed several times a week by the Hopi, and four tasks performed twice each day. Slow-cooking allows women to leave food unattended for periods of time, but requires wood for maintaining fires over periods of many hours and consequently a huge commitment of energy to fuel procurement. Since women are the primary caregivers in all human societies, the increased investment of time and energy in processing and cooking maize could not have been accomplished by simply rescheduling other tasks, but must instead have represented additional workloads for them (Claassen, 1991; Ember, 1983). Moreover, diminished mobility is likely to have promoted a shorter birth-spacing (Kelly, 1995) and a consequent increase in child care, adding to women's domestic responsibilities. Biological evidence for physical stress among late preceramic and early ceramic period populations in southern Arizona does indicate decreased levels of mobility among women in the initial ceramic period and (Ogilvie, 1999) and therefore it seems undoubtedly the case that associated technological indicia of food processing intensification reflect changes in female labor (Crown and Wills, 1995a,b).

Archaeological information from the pueblo-to-pithouse transition in the northern portions of the Southwest suggests that labor demands on women continued to grow as pithouse architecture became embedded in a larger architectural realm of surface rooms and features. The mano data presented by Hard *et al.* (1996) reflect a dramatic increase in size after A.D. 1000, especially in northern subregions (Fig. 7). These increases in mano size are paralleled by the appearance of functionally specialized mealing rooms where female task groups presumably milled maize together (Mobley-Tanaka, 1997). The range of form, size, and technological complexity in ceramics also increased during this architectural transition, reflecting both functional specificity and greater production costs (see Mills and Crown, 1995). Skeletal data from the Pottery Mound site in central New Mexico indicate that by A.D. 1300, Pueblo women were as residentially sedentary as modern agriculturalists (Ogilvie, 1999), suggesting that birth-spacing was probably diminished and the amount of time reproductive females spent rearing children had increased relative to preceding time periods.

In contrast to the early ceramic period when indicators of labor intensification are primarily found in food storage and preparation, evidence for labor intensification during the pithouse-to-pueblo transition in the northern Southwest includes the first formal agricultural field systems and possible land ownership markers, which are thought to indicate greater labor investment in crop production and fewer mobility options (Kohler and Van West, 1996). Cross-cultural ethnographic data reveal that agricultural intensification in grain-based economies involves greater absolute work loads for both men and women, but that women contribute relatively less to agricultural production (Ember, 1983). That is, men and women invest more time and energy in food production, but men especially begin to divert a greater share of their resources away from other activities, although women may still contribute a larger proportion of the overall labor (cf. Stevanovic, 1997). A key difference between men and women in these contexts is that while men may simply shift their labor away from other activities, such as hunting, women apparently add to their already high labor commitments in child care and food preparation (Ember, 1983). On this basis, I think it reasonable to assume that archaeological evidence for intensification of cultivation strategies and field maintenance during the pueblo transition meant that women's time allocation problems became greater and men were increasingly drawn into food production activities.

DISCUSSION

In tribal agricultural societies studied by ethnologists, the household is typically the fundamental unit of production and consumption. Households offer important economic advantages, particularly in the capacity to intensify production through restricted sharing of surplus and labor-pooling (Flannery, 1972; Netting, 1990) but the returns to sharing diminish rapidly when a cooperating network exceeds a few closely related households (Hegmon, 1989; Winterhalder, 1990). As a result, individual households maximize their economic power by minimizing social obligations to large groups (Kohler and Van West, 1996; Netting *et al.*, 1984).

Southwestern archaeologists often assume that pithouses were the domestic materialization of individual households (e.g., LeBlanc, 1983). However, this is not true ethnographically (Flannery, 1972; Gilman, 1987) and seems wholly impossible for the preceramic period when pit structure floor areas rarely exceeded 10 m^2. If structure size and configuration are a reliable guide, then the first evidence for pithouses with a capacity to sustain the overall domestic activities of a single household does not occur until the very end of the preceramic in some places, or the early ceramic period more widely.

This means that the best architectural evidence for even a rough equivalency between household production units and single dwellings covaries with multiple lines of archaeological evidence for economic intensification that were primarily in the realm of women's domestic activities.

These correlations suggest that the intensification of female labor evident during the early ceramic period might have been facilitated by the creation of housing that physically and symbolically demarcated individual households as units of production. The hearth is a powerful symbol of the domestic household (Haaland, 1997; Stevanovic, 1997; Watkins, 1992) and the expansion of pithouse size to incorporate all the means of production, from food processing and storage to tool manufacturing, around a central hearth may have significantly reinforced women's influence in economic affairs. Likewise, the widespread pattern of burial within pit structures during the early ceramic period may reflect an association between the household and its ancestors stemming from household ownership of critical resources. If pithouses were owned by women, then presumably the mortuary patterns indicate some female role in land tenure. I believe the construction of large, substantial dwellings capable of housing multiple individuals and exhibiting internal segregation of space into specific areas for food preparation, sleeping, and other domestic activities was probably the result of social changes away from relatively corporate or communal organization to systems based on household autonomy (Wills, 1990, 1992). In other words, households as the basic unit in subsistence production may not have become widespread in the Southwest until the late preceramic and early ceramic periods and when they did, were strongly associated with the domestic sphere, which suggests that the economic power held by women at this time may have been significantly greater than in preceding periods (also Crown, 1999).

Although pithouse size declined during the pueblo transition, pit structures remained a prominent residential form in the northern Southwest well into late prehistory, so that the projected structural role for this kind of architecture as an expression of economic independence probably continued to be important. Support for this view can be found in southern Colorado, where the first large pueblo villages were essentially aggregates of small household groups, with only loose centralized village authority at best (Wilshusen, 1990). From the perspective of women's workload, household aggregates probably helped women manage their increasingly complex time budgets by reducing the costs of child care, food preparation, and other domestic chores that accompanied economic intensification. Pueblos represent a huge expansion of formal domestic space relative to pithouses, and so the persistence of pithouses may well indicate that the household and its symbolic association with the hearth remained the core organizational principle for these societies. However, the eventual replacement of pithouses within large pueblo communities in late prehistory may signify a reduction in household economic autonomy, although it likely remained the basic unit of production. In this case, the loss of independence may have occurred as land tenure shifted from individual households to larger groups, such as clans (see Kohler, 1992; cf. Byrd, 1994). I am not arguing that the "power" that women had in social life was diminished, but rather that the context in which women gained power may have included more aspects of corporate obligation, beyond just household production (see especially Crown, 1999).

CONCLUSION

I think a plausible argument can be made that episodic changes in pithouse size and configuration in the prehistoric Southwest were part of economic intensification processes, but not greater "reliance" on food production. Instead, large pithouses during the early ceramic period may reflect increasing workloads for women and the emergence of households as relatively autonomous units of production. The absence of dietary change from the perceramic through the pithouse-to-pueblo transition, together with ample evidence for technological intensification in food processing, strongly points to diminishing returns from agriculture rather than an increase in productivity. Therefore, it appears that in the Southwest case, changes in domestic architecture were more closely linked to the organization of production than to agricultural surplus.

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