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Terrace Construction in Northern Chihuahua, Mexico: 1150 B.C. and Modern Experiments

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Around 1150 B.C. foraging bands in many parts of NW Mexico and the American Southwest were occupying small camps and building brush structures. At about the same time a dramatically more intensive occupation was underway at the site of Cerro Juanaqueña in northern Chihuahua, Mexico, where Native Americans constructed almost 500 terraces on a hilltop, expending levels of effort not evidenced in the Southwest for another 2000 years. In order to place this scale of effort in context we built an experimental terrace, made detailed volumetric measurements, estimated the total labor costs, inferred the nature of the labor organization, and evaluated terrace function.

Introduction

Over three thousand years ago maize and domesticated squash were first introduced from Mesoamerica into NW Mexico and the American Southwest. Until recently, several decades of archaeological research in Arizona and New Mexico seemed to indicate that the Archaic cultures that first received these crops were mobile hunting and gathering bands upon whom maize had little immediate impact. In all of the major physiographic regions of the Southwest, Native Americans appeared to have maintained a residentially mobile existence with minor use of domesticated plants until the beginning of the Christian era (e.g., Dick 1965; Haury 1962; Minnis 1992; Smiley 1994; Vierra 1994). Late Archaic period (1500 B.C.–A.C. 500) sites typically consisted of rockshelters with numerous storage pits and some hearths. Open sites were also used, particularly in the southern parts of the Southwest, and they usually consisted of a few shallow pithouses, pits, and hearths (e.g., Huckell 1995, 1997; Wills 1988a, 1988b). The effort involved in constructing the facilities on these sites was not substantial. Until recently it was thought that communities with reduced residential mobility and significant levels of maize use were not present until ca. A.C. 1–A.C. 500 (e.g., Haury 1950: 544–545, 1962; Minnis 1985, 1992). These later open sites contained larger numbers of more substantial pithouses and evidence of increased maize use. The appearance of ceramic vessel assemblages was a hallmark of this transition in the Hohokam and Mogollon regions but occurred somewhat later in the Anasazi region, and investigators have been examining the variability in the level of sedentism and agricultural dependence in these early pithouse settlements (e.g., Chisholm and Matson 1994; Gilman 1987; Hard 1997; Hard, Mauldin, and Raymond 1996). Nonetheless, these early pithouse settlements formed the basis of the expanding populations of agriculturalists in the Hohokam, Mogollon, and Anasazi culture areas and therefore understanding the processes leading up to the formation of these early villages is of critical impor-

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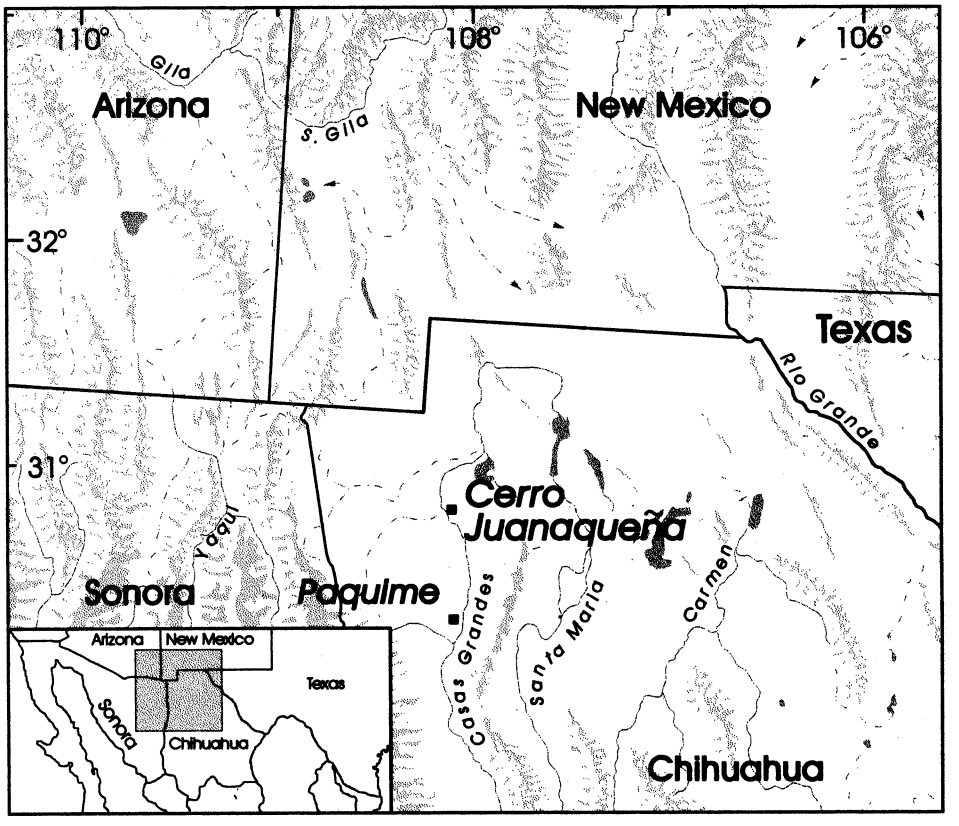


Figure 1. Map showing the location of Cerro Juanaqueña in NW Mexico.

tance in the American Southwest as well as adjacent NW Mexico.

The traditional model for the Late Archaic period indicated that small groups maintained a residentially mobile settlement system in which maize was only one of numerous exploited plant resources. This view has been modified by two recent discoveries in southern Arizona and NW Chihuahua. The first is a series of excavations at large Late Archaic period villages in SE Arizona and the Tucson Basin. These settlements formed along riverine floodplains and are characterized by numerous pithouses (up to 254 at the Santa Cruz Bend site) with hundreds of storage pits, and burials. Rates of maize recovery are high at these sites (Huckell 1995; Huckell, Huckell, and Fish 1995; Mabry 1998; Mabry et al. 1997). The second discovery consists of our excavations at the massive, Late Archaic period terraced village site of Cerro Juanaqueña in northern Chihuahua, Mexico (Hard and Roney 1998a, 1998b, 1999). Current work in these two regions is showing that during the Late Archaic period significantly larger groups aggregated into more sedentary settlements and relied more heavily on maize than archaeologists had previously thought (Hard and Roney 1998a, 1999; Huckell 1995; Mabry 1998). Here we discuss the significance of Cerro Juanaqueña's striking hilltop terrace complex, which represents a surprising level of effort for this time period.

The Site of Cerro Juanaqueña

About 1150 B.C. Native Americans built a complex of 486 terraces and 108 rock rings on the summit and slopes of a 140 m high basalt hill known locally as Cerro Juanaqueña. The number and scale of the constructed terraces are striking and challenge our existing notions regarding community size, regional population levels, degree of sedentism, role of agriculture, level of intergroup conflict, scale of land modification, and social and political organization 3000 years ago. One approach to understanding some of these issues is through consideration of the labor needed to construct this site. Labor investment is related to length of residential occupation, population size, labor organization, and social stratification (e.g., Abrams 1994; Binford 1990). Following in the tradition of other archae-

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Figure 2. View toward the NE of Cerro Juanaqueña with Rio Casas Grandes floodplain in the foreground. The macrofeature continues through "A-A′."

ological labor experiments (e.g., Ashbee and Cornwall 1961; Craig, Holmlund, and Clark 1998; Erasmus 1977, Jewell 1963), an examination of the construction and labor costs associated with these terraces is needed to place this site in its proper context relative to other earlier, contemporaneous, and later sites in the American Southwest and NW Mexico.

Cerro Juanaqueña lies 180 km sw of El Paso, Texas (FIG. 1) and 60 km north of the large 13th to 14th century A.C. pueblo of Casas Grandes or Paquimé (e.g., DiPeso 1974). Cerro Juanaqueña is located in Chihuahuan semi-desert grassland at an elevation of 1400 m (Brown 1982; Brown and Lowe 1983). Based on the town's currrent records, the mean annual rainfall at nearby Janos is 33.4 cm, with 65% of that falling between July and October. The summers are hot, with a mean daily July temperature of 24.8° C, and the mild winters yield a mean January temperature of 7° C. Nearby, the Rio San Pedro joins the Rio Casas Grandes forming a 4 km-wide floodplain. Cerro Juanaqueña overlooks this floodplain, abutting its eastern margin (FIG. 2).

The site is a *cerro de trincheras* (literally, hill with trench-

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Table 1. Six AMS ^{14}C dates from Cerro Juanaqueña.

*Provenience**	*Material†*	*Univ. of Colorado lab number*	*Age b.p. ± 1σ*	*Measured $\delta^{13}C$ ‰*	*Dendrocalibrated 2σ age range (intercepts)* B.C.‡
T537-74-4-55	Maize cob	3986	2890 ± 50	–9.9	910 (1030) 1250
T222-100-2-105	17 maize cupules	3995	2930 ± 50	–9.3	940 (1120) 1270
T6-93-1-74	Ocotillo	10056	2980 ± 70	–24.3	1020 (1200, 1250) 1380
T167-42-3-56	Maize cob	3983	2980 ± 50	–12.2	1020 (1200, 1250) 1380
T222-79-3-48	*Cucurbita digitata* or *foetidissima* type	10039	2980 ± 40	–23.6	1020 (1200, 1250) 1380
T222-94-3-95	*Cucurbita digitata* or *foetidissima* type	3985	3310 ± 60	–25.3	1430 (1530, 1570, 1600) 1740
Average of first 5 dates			2950 ± 20		1050 (1130, 1150) 1260

*Terrace-Bag-Unit-Depth below surface in cm
† Identification by Karen Adams (Hard and Roney 1998b, 1999)
‡Stuiver and Reimer (1993)

es or walls), a complex of hilltop terraces, rock rings, and stone walls. Cerros de trincheras have typically been associated with the large populations of agriculturalists in the Hohokam and Trincheras culture areas of southern Arizona and northern Sonora, Mexico (e.g., Johnson 1960; Sauer and Brand 1931; Stacy 1974; Wilcox 1979). They also have been identified in the Mogollon region of east central Arizona, southern Chihuahua, and in the Rio Sonoran basin in eastern Sonora (Hard and Roney 1998b; O'Donovan 1997; Pailes 1978; Roney in press). Although archaeologists have also applied the term "trincheras" to other rock wall construction types, particularly those related to water control, including bordered fields, weirs, and check dams (e.g., DiPeso 1974: 341; Donkin 1979; Herold 1965: 103–109; Howard and Griffiths 1966: 2), such water control structures are not involved here. Based principally on cross dating of surface ceramics, as well as some radiocarbon dates, most cerros de trincheras have been placed in the 12th–14th centuries with some, particularly in Sonora, dating as early as the 9th century A.C. (Downum, Fish, and Fish 1994; McGuire and Villalpando 1989; O'Donovan 1997). There is emerging evidence that the trinchera site of Tumamoc Hill, in Tucson, had an even earlier occupation (e.g., Fish, Fish, and Downum 1984).

Cerros de trincheras are typically situated on isolated hills and small mountains, frequently near major drainages. There is no consensus as to why these sites were constructed on hilltops. The most commonly cited interpretation is that they were used as defensive refuges (e.g., Fontana, Greenleaf, and Cassidy 1959; Johnson 1960; Sauer and Brand 1931; Wilcox 1979), although a number of researchers have proposed that some terraces were constructed as agricultural features (Downum, Fish, and Fish 1994; Fish, Fish, and Downum 1984; Huntington 1912). Many investigators have concluded that the cerros de trincheras served multiple functions, particularly as residential villages (e.g., Downum 1993; Downum, Fish, and Fish 1994; Fontana, Greenleaf, and Cassidy 1959; O'Donovan 1997; Stacy 1974). Evidence such as houses, household debris, grinding stones, and ceramics at many of these sites indicate that residential occupations were not unusual (Downum 1993; Fish, Fish, and Downum 1984; Hard and Roney 1998a, 1998b, 1999; O'Donovan 1997; Zavala 1998). The type site and largest one is Cerro de Trincheras in northern Sonora, which is thought to have been a population, political, and religious center between A.C. 1300 and 1450 and whose visual impact may have facilitated its role as a central place (O'Donovan 1997; Zavala 1998). Cerro Juanaqueña predates this and most other cerros de trincheras by about 2000 years.

Five AMS radiocarbon dates from Cerro Juanaqueña, including three on maize, yield a calibrated average of 1150 B.C. (TABLE 1). The sixth date is a statistical outlier, based on Stuiver and Reimer's (1993) procedures (Hard and Roney 1998a, 1998b, 1999). All samples were recovered either from the interior of the terrace rock walls or berms or from within the terrace fill behind the berms. In addition, we have recovered 235 dart points characteristic of the Archaic period. Most of the dart points are side-notched or corner-notched forms with expanding stems and straight or convex bases, forms that can be classified as San Pedro, Hatch, Hueco, or En Medio (Hard and Roney 1998a). Nineteen other points were found with deep basal notches and prominent barbs that resemble the Shumla

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type from the Lower Pecos region in Texas and the Diagonal Notched type from the Mogollon Highlands and Colorado Plateau (Berry 1987; Martin et al. 1952; Turner and Hester 1993; Turpin 1991). All of these types were used between 1500 B.C. and A.C. 1000 but were most common during the earlier part of this period (MacNeish 1993; Roth and Huckell 1992; Turner and Hester 1993; Turpin 1991). The other artifacts we observed that corroborate a Late Archaic age include over 500 slab and basin metates, small oval to round manos, tubular stone pipes, shallow stone mortars or bowls, small mushroom-shaped pestles, and stone cruciforms (Hard and Roney 1998a, 1999).

Evidence of use of the site following the Late Archaic is limited to five arrow points and about 30 petroglyphs, many of which date to the Medio (A.C. 1200–1450) and Historical periods. Pottery has only been found in two restricted surface locations (Hard and Roney 1998a: 1662). One is a single vessel dating to the Viejo period (A.C. 700–1200) and the other is a 10 m wide cluster of plainware sherds accompanied by a historical metal bowl. No evidence of site use after the Late Archaic has been found in the excavations. Evidence suggestive of site use prior to the Late Archaic is limited to two Cortaro projectile points, a form that spanned the transition between the Middle Archaic (3500 B.C.–1500 B.C.) and Late Archaic periods. Other point forms suggestive of Middle Archaic use are rare or absent in the collection (Hard and Roney 1998a).

The Late Archaic age of the site is particularly significant in light of the site's size—486 terraces and 108 rock rings built on a 6 ha area of the summit and upper slopes and a second 4 ha area on the western side of the hill just above the floodplain (FIG. 3). The terraces were constructed on the top and sides of the hill with slopes ranging from 5% to 40%. Native Americans constructed them by first piling local basalt cobbles, with little internal organization other than occasional stacks, to form berms that bow out in the center and pinch in at the ends against the slope (FIG. 4). Their cross-sections (FIG. 5) reflect a talus slope constructed at an acute angle that reached from 60–150 cm high above the original ground surface. The pocket between the apex of the terrace and the natural slope behind was then filled in with smaller rocks and finally sediment to form a level to slightly sloping surface. These surfaces are usually cleared of cobbles and have an average surface area of 51.5 sq m (sd = 44.1 sq m, range 2.4–290.6 sq m, n=486). Sometimes the apex of the berm rises as much as 50 cm above the platform surface to form a parapet. These parapets serve as retaining structures that prevent surface erosion and allow colluvial sediments to accumulate. About 40% of the terraces articulate with one another to form linear groups consisting of about two to five terraces. At least one macrofeature is present, consisting of 22 adjoined terraces plus two walls that form a 400 m long alignment along the northern, eastern, and southern site perimeter (FIGS. 2, 3).

The large number of terraces, their size, and organization indicate that the site was not constructed by the common social unit expected for the period, a single foraging band. In fact, sites of this scale are usually attributed to large agricultural societies with varying levels of sociopolitical complexity (Adler 1994; Cordell 1994, 1997). We sought to systematically evaluate the labor investment represented by the terraces in order to understand the sociopolitical organization of the builders through an analysis of energy investment in construction, known as an "architectural energetic" approach (e.g., Abrams 1989).

Methods

The site of Cerro Juanaqueña was initially noted during Charles DiPeso's (1974) fieldwork at Paquimé. Later Rex Gerald (1990) visited the site and briefly described the rock art and terrace features. Paul Minnis and Michael Whalen returned to the site during their 1994–1995 archaeological survey in the Janos area, during which Roney mapped the cultural features on the site and attributed them to the Late Archaic period based on surface artifacts. Our current investigation of the site began in 1997 and we have now completed the second year of a projected four-year-long program of mapping and excavation. To date we have excavated in a total of 13 terraces and 4 rock rings to obtain radiometric, ethnobotanical, faunal, and artifactual samples, as well as to better understand terrace construction. We have also completed a photogrammetric map of the entire site, as well as a more detailed topographic map covering a group of 68 terraces in the SE quadrant of the site.

Architectural energetics has rarely been applied to Archaic period or even egalitarian societies as most applications have focused on substantial public architecture (Abrams 1994; Callahan 1981; Craig, Holmlund, and Clark 1998; Erasmus 1977; Jewell 1963; Peebles and Kus 1977). We built two terraces in order to better assess the energetics involved in their construction. These replications yielded insights regarding: 1) construction methods; 2) volume of fill; 3) labor costs; 4) the minimal level of labor organization for such an undertaking; and 5) construction methods (Abrams 1994). Based on the site topographic data we estimated the total volume of the features and then extrapolated our experimentally-derived labor rates to estimate the labor involved in the construction of the entire site.

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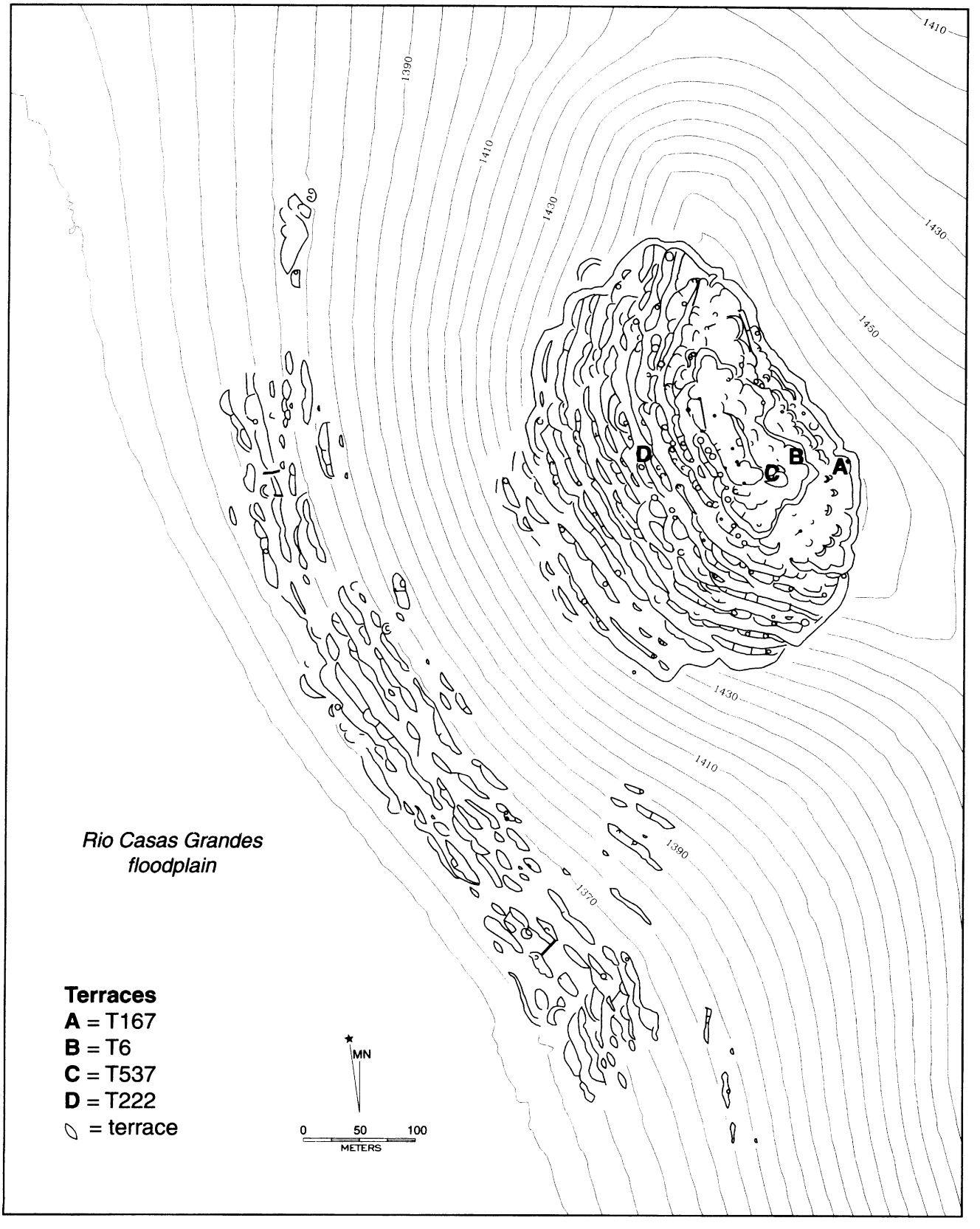


Figure 3. Cerro Juanaqueña plan view and radiocarbon date proveniences.

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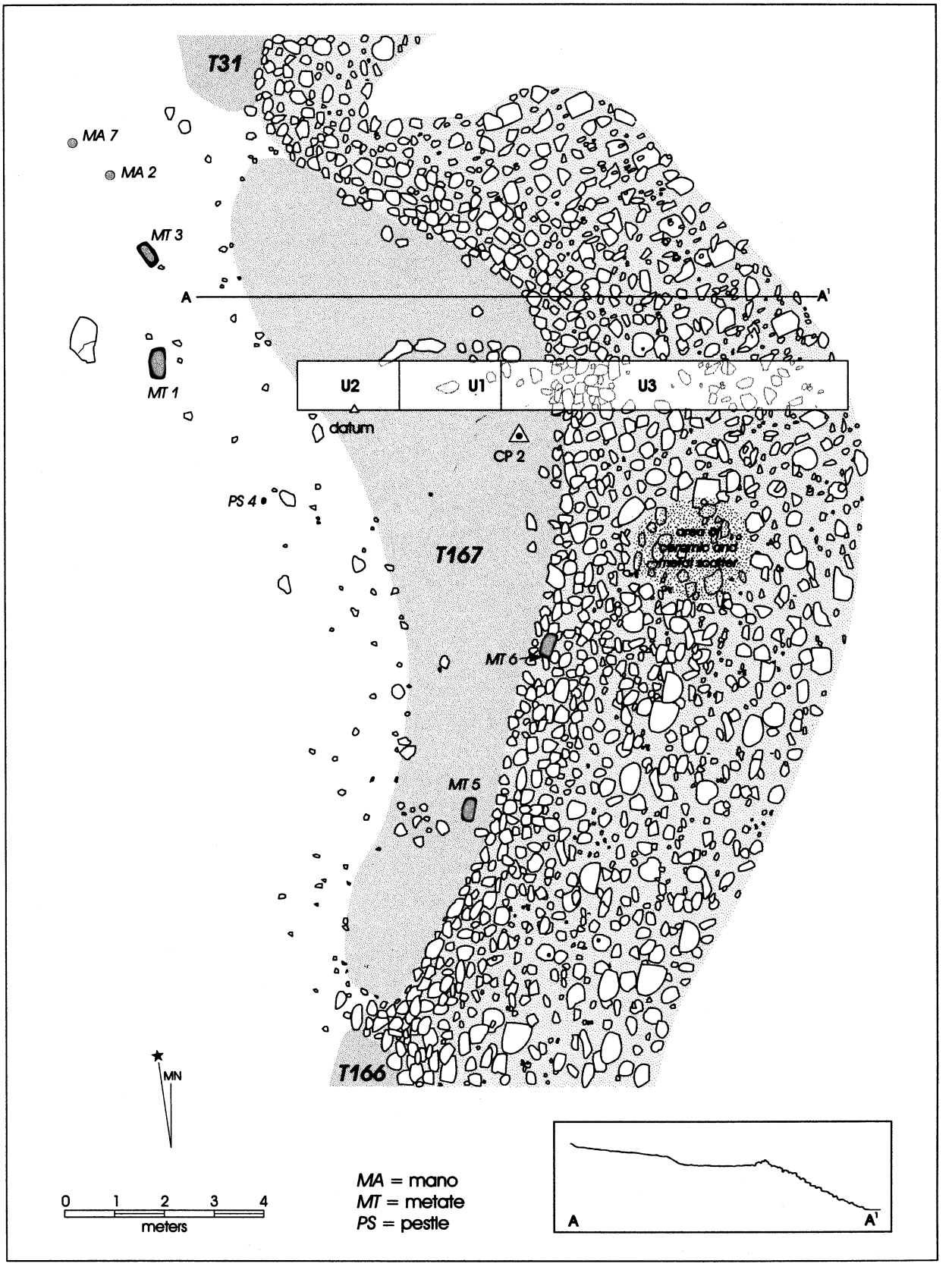


Figure 4. Plan view of Terrace 167.

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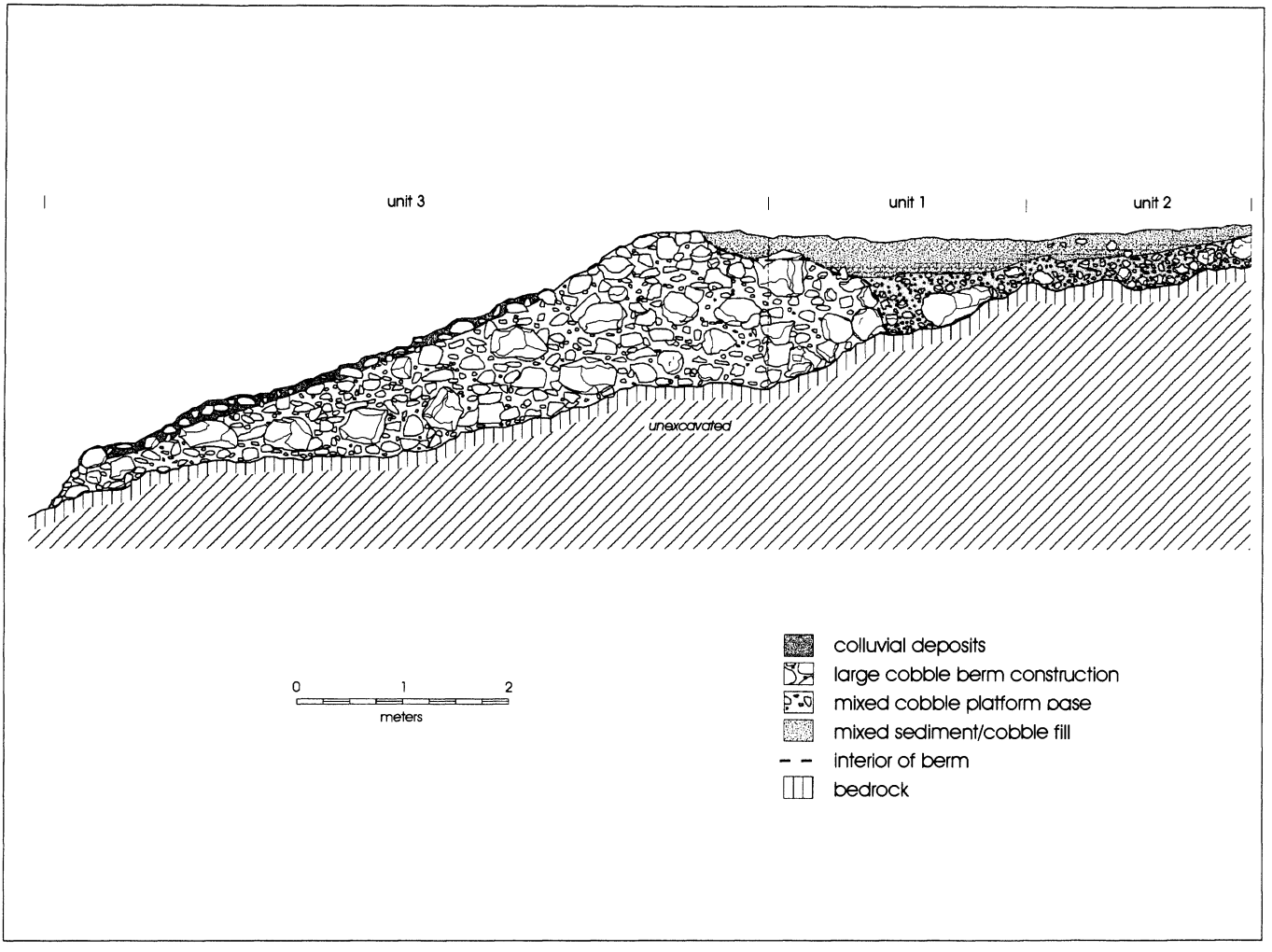


Figure 5. Profile of Terrace 167.

Labor Estimates

We roughly constructed our first terrace, about 10% of the volume of an average prehistoric terrace, in a little over a day; the work went rapidly with few significant problems. We developed construction and recording procedures that allowed the work to go smoothly while collecting time and volumetric data.

We next constructed a second, full-sized terrace on a hill immediately north of Cerro Juanaqueña. The spot had no archaeological features and resembled Cerro Juanaqueña with a slope of about 20%, thin soil, and abundant basalt cobbles on the surface. Two local men worked under the supervision of Zapata, who also participated in the work, maintained a log of all activities and time expenditures, and documented the work through video and still photography. Tools included wooden digging sticks, a metal pick, and metal buckets.

There were five construction phases: 1) clearing the vegetation; 2) outlining the feature with rocks; 3) constructing the berm; 4) filling the pocket between the berm and hill slope with rock rubble; and 5) capping the platform with sediment. Figures 6 and 7 show the dimensions of the completed structure and Table 2 lists the time required for each of these activities.

The incidental effort required to stomp and pull up the few small shrubs on the site required only a half an hour. Next, medium to large (20–40 cm diameter) cobbles were used to outline the crescent shape, requiring only 45 minutes since many in situ rocks formed the initial layer of the berm. The construction of the berm then began in earnest. All of the rock used in construction was taken from a mea-

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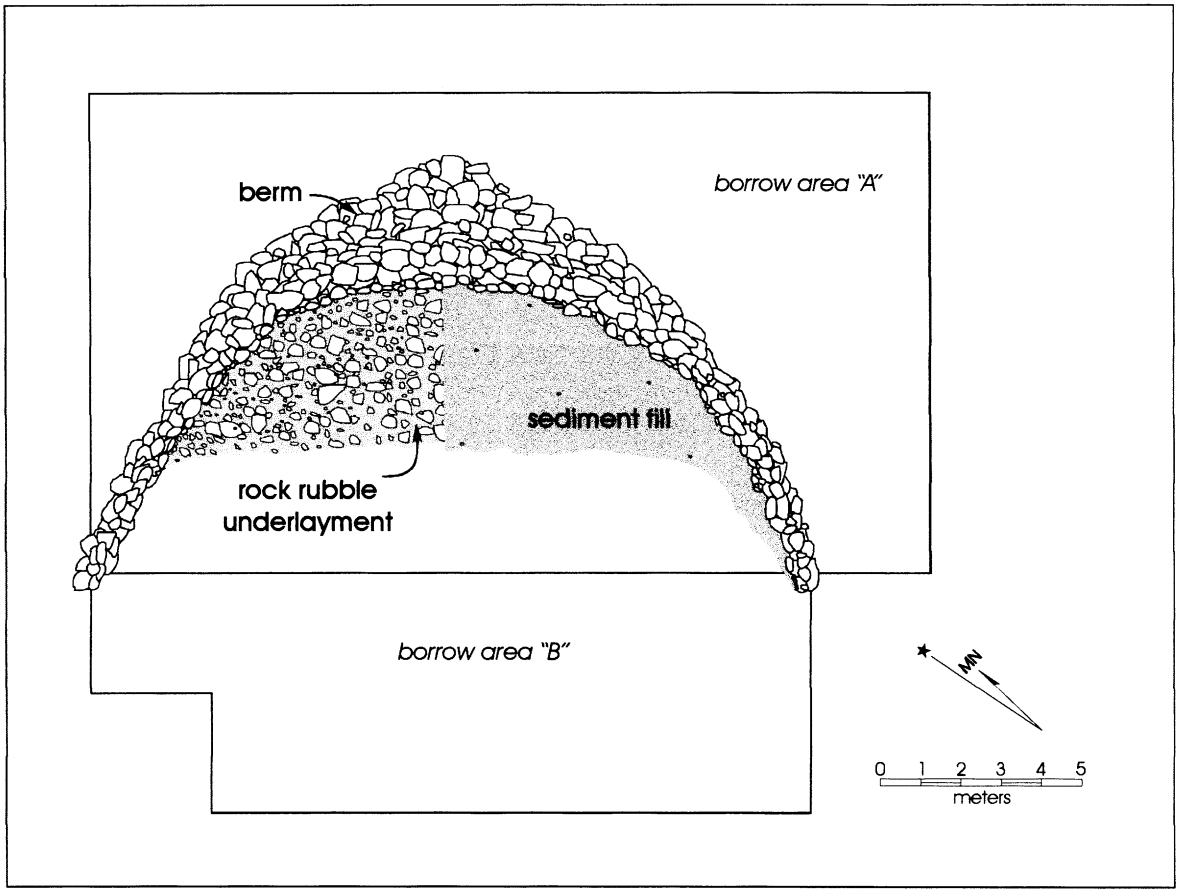


Figure 6. Plan view of experimental terrace.

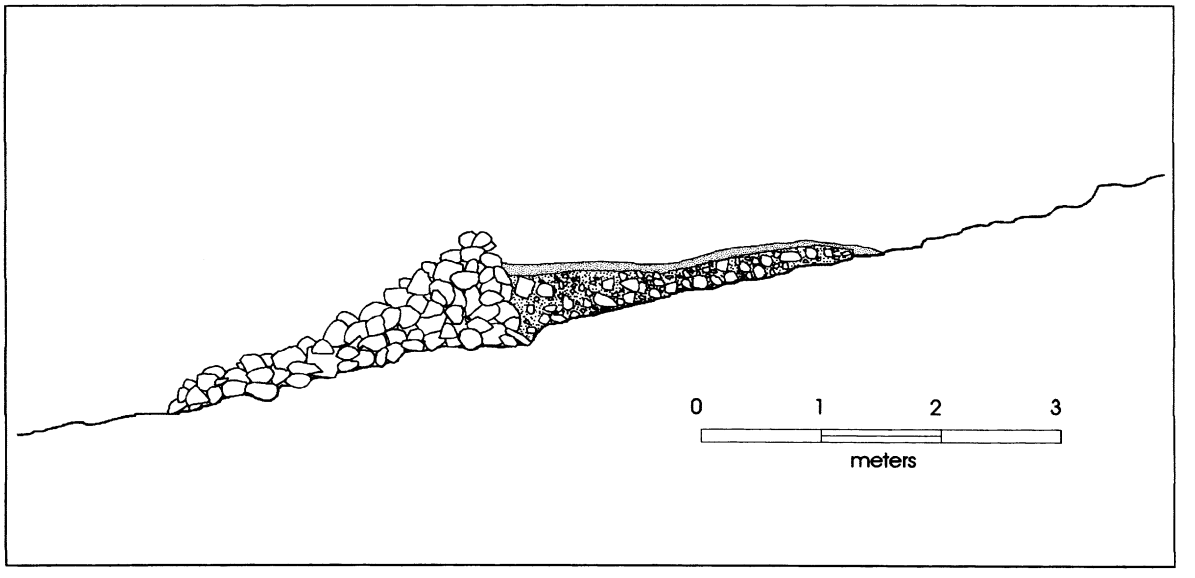


Figure 7. Profile of experimental terrace.

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Table 2. Experimental terrace labor data.

Task	*% completed*	*Person hrs*	*Person hrs extrapolated for 100% completion*	*Materials cu m*	*Materials cu m extrapolated for 100% completion*	*Person hrs per cu m*
1. Site clearing	100	0.5	0.5	–	–	–
2. Layout terrace	100	0.75	0.75	Included with rock berm below		
3. Rock berm	95	20	21.1	20.4	21.5	1
4. Rock platform	100	12.8	12.8	8	8	1.6
5. Sediment cap*	50	14.9	29.8	2.1	4.2	7.1
Total			65		33.7	1.9

*Assuming 100% work with digging sticks.

sured and bounded 350 sq m area surrounding the feature. Initially workers heaved 6 to 40 cm diameter cobbles down slope into the outlined feature. As loose surface rocks near the feature were exhausted, the team moved farther away and tended to select and toss only smaller rocks, while the larger ones were rolled down toward the growing terrace. A few of the largest rocks had to be carried by two men and placed on the berm wall. Maximum transport distance was only about 15 m, with 6–10 m more typical.

By the beginning of the third day the surface rock within the marked source area had been exhausted so that rocks had to be dug out from the rocky, shallow, upper sediment. This effort was substantially slower. Two individuals dug while a third person picked up the rock and tossed it onto the growing berm. As the loose surface rock near the terrace became exhausted some slightly buried rocks were pried loose with digging sticks. To reduce fatigue the men alternated among digging, picking up, and throwing large and small rocks. We completed about 95% of the rock berm and if the full task had been finished it would have required about 21 person hours (TABLE 2). The fourth phase of construction involved filling the pocket between the berm wall and the hill slope with cobbles to form the platform. This work went rapidly as cobbles were tossed into the area and the platform was filled with rubble to create a level terrace surface. Approximately 13 person hours were required for this phase.

The fifth and final phase, following the prehistoric pattern, consisted of capping the stone platform with a layer of sediment. We determined that we could gain the needed labor rate data by only covering the south half of the platform. For the first two hours the team used digging sticks to loosen the shallow, silty, hard-packed sediments in the material source area. The dirt was scooped up by hand and put in 12-liter metal buckets and then dumped on the platform. We felt the metal buckets probably did not offer a significant advantage, tool costs aside, over the presumed use of prehistoric baskets as containers, although the buckets would be more durable. After two hours we had obtained enough work data with the digging sticks to determine the number of buckets per hour that could be filled, transported, and dumped. We then switched to a handpick for the remaining three hours of work. Accurate records were kept of the number of buckets of earth carried and dumped and the tools used, and these show that the use of a pick resulted in a 30% increase in the rate of work for this phase. Applying this correction to the actual amount of time spent and doubling the result to account for covering the entire terrace surface (rather than just the south half) we estimate that this task would have required 30 person hours to complete (TABLE 2).

Another important aspect of the terrace-building experiment was estimating the volume of stone and earth used for different phases of construction. To estimate the volume of rock we defined a 3 × 3 m sample area within the rock collection area. Prior to construction, all of the cobbles within the sample area were tabulated in 5 cm-interval categories based on their diameter. The volume of rock representative of each ordinal category was calculated using the formula for the volume of a sphere multiplied by the number of rocks in each category. These calculations show that each square meter contains, on average, 0.081 cu m of stone. The 350 sq m borrow area was subdivided into Areas A and B for the berm and terrace platform respectively and yielded a total of 28 cu m of rock (FIG. 6, TABLE 2).

We estimated that about 4.2 cu m of earth would cap the terrace surface based on the number of 12 liter pails we dumped on the south half of the terrace surface. The completed experimental terrace involved approximately 34 cu m of rock and sediment and took 65 person hours.[1] We

1. As a result of additional fieldwork and further analyses, this and a number of other values in this paper represent modifications of estimates published in Hard and Roney (1998a).

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were then able to estimate the labor cost for rock and sediment combined as 1.9 person hours/cu m. Note that the rock component rate at 1.15 person hours per cu m proceeds much faster than the sediment portion at 7.1 person hours per cu m.

Is our experimentally-derived rate of 1.9 person hours per cu m of rock and dirt a valid approximation? The closest comparable data are from simple procurement experiments that do not include transport or building activities and serve to show our results are consistent with previous labor rate experiments. A Honduran Maya man procured cobbles from a river bed at the rate of 2.1 hours/cu m (Abrams 1994: table 3) and a Sonoran Mayo man, using a digging stick, dug and placed in cans an average of 1 cu m of dirt every 1.9 hours (Erasmus 1977: 61). Finally, a rate of 1.8 hours per cu m of earth is based on an average of laborers in five countries that use metal tools (United Nations 1961: table 1). Our dirt-only rate of 7.1 person hours per cu m, however, is much slower than these and probably reflects the greater cost of excavating the hard, rocky, shallow soil with digging sticks plus our transport distance, however short. But these previous studies indicate that our combined rock and dirt construction rate of 1 cu m in 1.9 person hours (TABLE 2) is a reasonable estimate. Therefore the archaic terraces were constructed 9–14 times faster than other experiments involving transporting materials and constructing masonry walls as the activities are quite different (Abrams 1994; Arnold and Ford 1980; Erasmus 1977; Lekson 1984: 285). At Cerro Juanaqueña rocks were simply picked up, tossed, or sometimes rolled a short distance and then dropped into place: transport costs were low, the stones were unmodified, and their assembly involved little care.

Volume Estimates

We estimated the volume of all the prehistoric terraces on Cerro Juanaqueña by determining the mean area of a terrace cross-section and multiplying it by the total length of all the terrace walls. The civil-engineering cross-section method allows estimation of irregular volumes by multiplying average cross-sections by length (O'Rourke 1940). Based on a sample of 26 terraces for which we had detailed measurements, we determined that the mean cross-section of a terrace on slopes greater than 10° was 4.5 sq m (sd = 2.3 sq m, n = 21) and 1.05 sq m (sd = 0.35, n = 5) on slopes of 10° or less. For each of the 486 terraces we measured the perimeter berm length and its ground slope category using ArcView, a geographic information system. There are 1.4 km of berm wall on the shallow slopes and 6.6 km on the steep slopes for a total length of 8 km of all berm walls. By multiplying the berm length by the appropriate average cross-section area we estimated that there was a total of 31,000 cu m of rock and sediment used in the construction of 486 terraces. Based on our excavation profiles we were also able to estimate that, on average, 85% of a terrace volume is rock and 15% is sediment. This represents about 51,000 metric tons of rock (conversion is 1.954 metric tons/cu m) and about 5800 metric tons of sediment (1.249 metric tons/cu m; Glover 1989). Using the rate of 1.9 person hours per cu m of rock and dirt, the total cost of all terraces was estimated next. The estimated total effort of 60,000 person hours is about 30 person years based on a common traditional work pattern of 6 hour days, 300 days per year, making an 1800 hour work year (Barlett 1980: 80; Erasmus 1977: 59; Turner 1983a, 1983b).

Discussion

Scale of Labor Investment

Comparing these labor estimates to those from elsewhere in the Southwest allows us to assess the scale and organization of labor at Cerro Juanaqueña and to make inferences regarding terrace function (e.g., Doolittle 1984; Erasmus 1977). As residential features, the terraces at Cerro Juanaqueña can be compared to the labor costs of pithouse and pueblo architecture. The terraces at Cerro Juanaqueña have labor costs roughly equivalent to about 125 large Anasazi-style pithouses (5 × 5 × 1.5 m deep), with support posts and roof, based on Glennie (1983) and Wilshusen's (1988: 608) estimate of 79 six-hour person days to construct one. For pueblos, Varien's (1984) reconstruction, summarized by Wilshusen (1988: 611), estimated that the construction of the first suite, consisting of a room plus two storage rooms, would take 71 six-hour person days, enclose 22 sq m, and involve the use of both masonry (unshaped rock laid in mud) and jacal. Each additional suite would take 53 person days to construct since most rooms would share one wall with a previously built room. Therefore Cerro Juanaqueña is equivalent to about a 550-room pueblo consisting of 185 living rooms and 370 storage rooms. Sites of this magnitude were generally (except perhaps in southern Arizona) not constructed in the Southwest until late in the first millennium A.C., 2000 years after Cerro Juanaqueña (e.g., Cordell 1997: 238–239).

Several researchers have proposed that late prehistoric cerros de trincheras were intended for display (Haury 1976: 348; O'Donovan 1997). In this context it is interesting to compare Cerro Juanaqueña with other monumental constructions from a variety of contexts around the world, and they can be interpreted from a number of dif-

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ferent theoretical perspectives (e.g., Demarest 1989; Drennan 1976; Lawrence and Low 1990; Low 1995). Here, monumental constructions are defined as projects that involve significant labor investments and have a primary role of symbolic expressions related to social organization and ideology.

Great kivas, built by peoples of the Mogollon and Anasazi traditions in the Southwestern United States, are square or circular subterranean roofed structures typically about 10 m in diameter and 2 m deep. These features are associated with small farming communities of 130 to 160 people occupied between A.C. 500 and 1200 (Adler and Wilshusen 1990). Based on Glennie's (1983) pithouse reconstruction experiments, Lightfoot (1988: 267) estimates that the Grass Mesa great kiva in SW Colorado required 8850 person hours or about 5 person years at 1800 hours per year to construct. Therefore Cerro Juanaqueña represents the labor equivalent of about six great kivas.

Prehistoric roads associated with the Chacoan Culture (A.C. 1000 to 1150) in NW New Mexico have been interpreted as monumental constructions (Roney 1992; Sofaer, Marshall, and Sinclair 1989). These are long swales excavated 20 cm or so into the ground, and perhaps 7 m in width. Spoils from the excavation were piled on either side to create berms with a total berm-to-berm width of 9 m. The longest of these constructions are the North Road and the South Road, both emanating from Chaco Canyon. Each of these would have involved moving about 35,000 cu m of soil. Using our rock and fill estimate of 1.9 person hours per cu m, construction of each of these "roads" would have required about 37 person years of work, implying that they each represent a labor investment comparable to that at Cerro Juanaqueña. Based on these comparisons, the construction effort at Cerro Juanaqueña is similar to that of constructing a 125-room pithouse village, a 550-room pueblo, six great kivas, or one of the principal Chaco roads.

Terrace Function

Some of the terraces on cerros de trincheras sites have been considered agricultural (e.g., Downum, Douglas, and Douglas 1985; Fish, Fish, and Downum 1984; Huntington 1912), based on their general morphological similarity with known agricultural terraces. Evidence used in support of an agricultural function include the potential of a significantly longer growing season due to terrace locations above cool air inversions; the recovery of maize pollen from terraces; macrobotanical evidence of potentially cultivated plants such as agave; and terrace orientations that potentially would have provided more favorable exposures (e.g., Downum, Douglas, and Douglas 1985; Fish, Fish, and Downum 1984; Hack 1942: 20). To evaluate the possibility that the Cerro Juanaqueña terraces were agricultural we considered the labor costs and potential productivity of farming these terraces.

Prehispanic Maya agricultural terraces have been estimated to have been built at the rate of 4.3 person hours/cu m (Turner 1983a: table 2.2, 1983b: 108–109) and modern Mexican laborers are expected to construct terraces in rocky soils at the rate of 4.8 hrs/cu m (Wilken 1976: table 1). In contrast the Cerro Juanaqueña terraces were built at a rate of 1.9 person hours/cu m or less than half the cost per unit of volume. The more costly Maya terraces were built of stacked slabs and the modern Mexican terraces involved digging drainage channels and piling the dirt into embankments, techniques that contrast with the more casual, rapid rock-piling method at Cerro Juanaqueña.

We can also examine terrace labor cost on the basis of potential planting area per hectare. Based on our ArcView measurements, the total flat surface area created by the terraces at Cerro Juanaqueña is 2.5 ha, so the construction costs of this terraced land would be about 4000 person days (1 day=6 hrs) per ha of planting surface. In contrast, agricultural terraces in the Maya region are estimated to have construction costs of approximately 100–850 person days/ha of planting area, based on a 6 hr work day (Turner 1983a, 1983b: 108). Modern Mexican labor data suggests that a hectare of forward-sloping terrace land could be constructed in 45–100 person days and flat bench terraces in 130–260 person days/ha (Wilken 1976: 417–418). Thus, if Cerro Juanaqueña terraces were constructed for farming, their labor cost was more than four times the cost per hectare expended by the Maya in their highly intensive farming systems. In fact, this level of investment is even greater than for Maya raised fields, which are estimated to have construction costs between 945–3020 person days per ha (Turner 1983a: 15). Moreover, high-cost labor investment in agriculture occurs under conditions of high population densities relative to production or severe environmental degradation (e.g., Boserup 1965; Turner 1983b). There is nothing to suggest Late Archaic populations even approached this level of occupational intensity or engaged in such intensive agricultural practices. Finally, if the total of 2.5 ha of flat surface found behind all 486 terraces were planted in maize, the harvest would support about four adults for a year, assuming each adult could be supported on approximately 0.6 ha per year (e.g., Hard and Merrill 1991). Doolittle (1985: 286) similarly argues that small prehistoric terraces in the Mogollon region of New Mexico may have been impractical for planting.

Based on the energetics alone it appears that construct-

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ing these terraces for farming would be impractical. In fact, little about these terraces would appear appropriate for farming. Spencer and Hale (1960) discuss types of agricultural terraces and point out that when nearly horizontal terraces are constructed across the slope, particularly in arid areas, they are constructed to be irrigable with a slight end-to-end gradient, a type of terrace common in Mesoamerica and South America (Spencer and Hale 1960; Donkin 1979). In addition, having an essentially horizontal surface is not necessary for successful planting and agricultural terraces are frequently built with substantial forward slope (Donkin 1979; Spencer and Hale 1960; Wilken 1976), reducing fill requirements and labor costs appreciably.

The Cerro Juanaqueña terraces were constructed with nearly horizontal surfaces that have only slight forward slopes and, often, parapets that rise above the surface of the berm 10 to 50 cm. The parapets impeded soil erosion and run-off to the terrace below. Neither do the terraces have any end-to-end gradients or other features that would serve to guide water from one terrace to another. Since the terraces at Cerro Juanaqueña were built in an arid region and consist of multiple horizontal terraces built on slopes at a significant cost with no apparent irrigation features, they contrast with all ten agricultural terrace types discussed in Spencer and Hale's review.

Some terraces constructed above cold air inversions may have extended the growing season, but cool weather farming still requires soil moisture (e.g., Fish, Fish, and Downum 1984; Hack 1942: 20). Unlike the Sonoran Desert, the northern Chihuahua Desert has only a summer dominant rainfall pattern, with little precipitation in the winter or spring; cool weather rainfall dependent farming would have been unreliable. For example, in Janos from November to May, rainfall averages only 9.9 cm out of the total annual 33.4 cm. The thin soils on the Cerro Juanaqueña terraces do not appear to be particularly suitable for farming. Finally, the terraces are located above a 4 km wide floodplain that provides far superior arable land and is farmed today.

It appears that most of the Cerro Juanaqueña terraces were constructed as house platforms and related features. The terrace surfaces contain ample evidence of household debris, including heavily worn, massive basin metates, manos, projectile points, chipped stone debris, and bone. Excavations into these terraces reveal dense midden deposits containing ashy sediment, charcoal, charred maize, dense burned and unburned bone, significant quantities of flakes, and occasional projectile points. These materials are widespread across the site and common in the terrace excavations. While no houses have been defined, we have found two small postholes and compacted occupational surfaces on terraces (Hard and Roney 1998b). Given a domestic function for these platforms, it would not be surprising if families maintained small household gardens as part of the residential function.

Labor Organization

A key issue regarding labor costs and organization at Cerro Juanaqueña is the period of time and number of construction episodes over which the site was built. We can only make preliminary inferences until we obtain additional radiocarbon dates from numerous contexts throughout the site. The available radiocarbon dates suggest a short period of occupation since the 2σ calibrated mean of five dates has a range of only 210 years (TABLE 1), although we do not yet know if the site was built quickly or in increments over the course of its occupation.

Assuming Cerro Juanaqueña was constructed over a relatively short period of time, does the scale of the construction suggest social ranking or complex levels of labor organization? Abrams (1989) and others describe several dimensions of architectural energy investment that are related to sociopolitical complexity. For example, construction that involves complex steps or a sequence of steps may involve specialists or a hierarchical organization, but the simple terrace constructions at Cerro Juanaqueña would not have required specialists or a ranked organization (Arnold 1993; Udy 1959).

The energy expended in domestic architecture is related to the level of sociopolitical complexity (Abrams 1989). The average labor cost of each Cerro Juanaqueña house platform is about 120 person hours or about 20 person days, based on a 6 hour day. The cost of a superstructure aside, the labor investment for a house platform is somewhat greater than the two or three days required to construct a seasonally occupied forager's hut or wickiup (Lee 1979: table 9.10) but less than the 70–80 person days needed to construct a large, substantial pithouse or pueblo room suite. It is also less than the 65–130 person days needed to construct a Maya commoner's wattle and daub residence and at least two orders of magnitude below the several thousand person days needed to construct a masonry residence on a raised platform in a Maya urban barrio (Abrams 1989).

We have not yet identified any public architecture at Cerro Juanaqueña, although public structures among egalitarian semisedentary and sedentary societies are quite common (Adler 1989; Drennan 1976). Our mapping and surface survey have revealed no mounds, public platforms, or above-ground ceremonial walled spaces representing large-scale communal architecture such as those associated with the Paquimé, Hohokam, or Trincheras culture sites

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including cerros los trincheras sites (Craig, Holmlund, and Clark 1998; Fish, Fish, and Downum 1984; O'Donovan 1997; Zavala 1998). Given the extensive surface visibility and shallow deposits at Cerro Juanaqueña, if communal architectural features are present, it is unlikely that they involve significantly higher levels of labor than the domestic terraces.

Given the absence of any evidence for social ranking, it is likely that a small, family-based labor unit would construct a terrace for their house platform within a few days. Donkin (1979: 133) notes too that traditional agricultural terraces are commonly built by families. They may have had the assistance of kinsfolk or unrelated individuals but in so doing they probably incurred a social debt. Even assuming a relatively short period of occupation and rapid site growth, the evidence at hand suggests an egalitarian social organization and family based labor units.

While family units appear to be the most plausible level of labor organization, there are indicators of site planning and internal spatial organization at Cerro Juanaqueña. The most substantial evidence of this is the encircling macrofeature, consisting of 22 joined terraces and 2 walls that form a partial northern, eastern, and southern site perimeter (FIGS. 2, 3). On the eastern perimeter this feature is oriented perpendicular to the hill slope and creates a series of contiguous terraces, forming a largely continuous surface approximately 300 m in length. Along the northern and southern perimeter the feature curves around to run parallel to the hill slope. Here it consists of a large, massive cobble berm against which a number of terraces abut. The continuous nature of this feature and the fact that it cross-cuts multiple domestic terraces suggests that its construction involved the cooperation of numerous domestic units, while the homogeneity and unbroken nature of this macrofeature suggests that it was built as a planned construction within a short period of time as opposed to being an agglomeration of multiple, unrelated construction episodes.

Small clusters of two to five terraces exist throughout the site. These are typically built at the same contour and are subdivided by either the sinuous nature of the berm wall or by small cross walls perpendicular to the berm wall. Individual terraces built at the same contour also tend to form consistent bands across portions of the slope. In addition, there is roughly even spacing among bands of terraces moving down slope. No doubt some of these organizational aspects are the result of using the natural topography of the hill to best advantage, but there is an overall pattern and symmetry to the site that indicates planning. It is difficult to imagine that this level of organization could be the product of many families making independent decisions. Instead it is likely that aspects of terrace construction, particularly their spatial distribution, were under the direction of a recognized leader. Johnson (1982) suggests that with six or more organizational units leadership positions are usually recognized. Given the size of the site, it is likely that more than this number of family units were engaged in construction efforts simultaneously.

Egalitarian societies frequently recognize leaders by their age or skill, for particular tasks such as hunting or raiding. Typically these leaders have no coercive power and their position of authority is extended only for the duration of the task. Cerro Juanaqueña's internal organization suggests that family units recognized one or more leaders who directed the placement of many of the terraces.

Conclusions

The site of Cerro Juanaqueña was constructed around 1150 B.C., during the early introduction of maize into the Southwest. Its 486 terraces contain about 31,000 cu m of stone and sediment and represent about 30 person years of labor. Although the combined volume and time are great, the uncomplicated task of building these terraces proceeded at a faster rate than that of most prehispanic stone construction projects. The total labor costs of constructing Cerro Juanaqueña is roughly equivalent to a 125-room pithouse village, a 550-room pueblo, one of the principal Chaco roads, or six great kivas. Sites of this scale are generally unknown in the Southwest until 2000 years later. While many terrace features in the Southwest and NW Mexico have been interpreted as agricultural features, the Cerro Juanaqueña terraces are too energetically costly to have been constructed for this purpose; if all the terraces were planted in maize, the harvest would support only four adults for a year. Instead most were constructed as house platforms, over a relatively short period of time, by family-based labor units under the direction of a leader who coordinated overall site planning and layout. Future research will explore why these house platforms were constructed on a hilltop, the level of sedentism, the nature of the subsistence base, and the role this site played in the formation of agrarian settlements.

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