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#### **Authors**

Ahlstrom, Richard V. N.  
Roberts, Heidi

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# Desert Pavement and Buried Archaeological Features in the Arid West: A Case Study from Southern Arizona

RICHARD V. N. AHLSTROM and HEIDI ROBERTS, HRA, Inc.,  
8544 Summer Vista Avenue, Las Vegas, NV 89128

*The interpretation of surface artifact scatters presents a challenge to all archaeologists, including those who work in the deserts of the American West. In some circumstances, a sufficiently dense and diverse artifact assemblage can indicate the presence of buried pit houses or other evidence of habitation (Czaplicki and Ravesloot 1989). At the opposite extreme, there are artifact scatters of low density and diversity that are often assumed to be exclusively surface manifestations, unlikely to be accompanied by significant subsurface remains. This is especially true when the artifacts are scattered on top of, or are incorporated in, desert pavement.*

**D**esert pavement has been defined as “a thin surficial layer of stone fragments...overlying a soil layer in which few fragments occur” (Williams and Zimbelman 1994:243) or again as “a one-pebble-thick concentration of gravel that mantles a stable surface” (Waters 1992:204). Pavements typically overlie a layer of fine-grained sediment, often referred to as an Av horizon. Desert pavements occur in arid regions throughout the world (Cooke 1970:560; Symmons and Hemming 1968), including the deserts of southeastern California, southern Nevada, southwestern Utah, western Arizona, and northwestern Sonora. Throughout this region, desert pavements are associated with archaeological sites that may include surface artifact scatters, circular clearings in the pavement, rock rings intruded into the pavement, or some combination of artifacts, clearings, and rock rings (Antanaitas, Schneider, and Warren 1995; Blair and Fuller-Murillo 1997; Byrd and Palette 1998; Carrico and Quillen 1982; Ezzo and Altschul (1993); Hayden 1967:336-338; Hunt 1960; Marmaduke and Dosh 1994:1; Rogers 1939:7-8; Stone 1991:68-76; Stone and Dobbins 1982; Sutton 1988:64). The clearings and rings have been referred to variously as cleared circles, sleeping circles, sleeping clearings, rock rings, rock circles, and vision circles. These features are generally considered unlikely to include a subsurface component (Blair and Fuller-Murillo 1997:11; Stone 1991:74-76). This assumption follows, at least in part, from the functional interpretation of cleared circles and rock rings as sleeping places, and of rock rings as supports for shelters that were only briefly inhabited or as places for seeking a vision (Blair and Fuller-Murillo 1997; Ezzo and Altschul 1993; Stone and Dobbins 1982). It has even been argued that some cleared circles, of the kind recorded by archaeologists, are natural, rather than cultural, in origin (Antanaitas, Schneider, and Warren 1995:37, 66; Hunt 1975:171; Stone 1991:76). Thus, the presence of cleared circles or rock rings on a desert-pavement site is not, on its own, generally considered to contradict the idea that the site is likely to be primarily, if not entirely, a surface manifestation.

The expectation that archaeological sites located on desert pavement will not extend below the ground surface is supported by three kinds of evidence. First, there are a number of instances in which excavation units placed in artifact scatters, cleared circles, and rock rings in desert-pavement settings have failed to contain buried cultural remains (Antanaitas, Schneider, and Warren 1995:66). Examples include excavations conducted in Death Valley and on the Twentynine Palms Marine Corps Base in Southern California (Hunt 1960:184-187; McDonald, Flenniken, and McCarthy 1996), at the northern edge of the Las Vegas Valley in southern Nevada (Ahlstrom and Roberts 2001), along the routes of the Granite Reef Aqueduct and Palo Verde to Devers Transmission Line in west-central Arizona (Carrico and Quillen 1982; Stone and Dobbins 1982:249-250), at Painted Rock Reservoir, also in west-central Arizona (Brew 1981), and on the Yuma Proving Ground in extreme southwestern Arizona (Marmaduke and Dosh 1994; Frederick Briuer, Army Corps of Engineers, personal communication 2000). Second, geomorphological studies have suggested that desert pavements develop over time scales of thousands of years (McDonald, McFadden, and Wells 1995). According to McFadden, Ritter, and Wells (1989), "In perhaps as little as 20,000-35,000 yr, the initial bar-and-swale topography of alluvial fan surfaces of the Soda Mountains piedmont has been converted to a strongly varnished, essentially flat stone pavement" (1989:288, emphasis added). Third, many desert-pavement surfaces have been dated as having formed in the late Pleistocene or early Holocene epochs, thousands of years before the creation of the associated archaeological sites (Hayden 1967, 1976; Pearthree 2000). Under these circumstances, artifacts may have worked their way into a pavement, and features may have intruded through it, but neither artifacts nor features can underlie it (cf. Waters 1992:207-208). This relationship between old pavements and younger archaeological sites is encapsulated in Hayden's (1965:272) concept of the "fragile-pattern area," defined as "any archaeological area in which man's material remains lie without depth upon an existing natural surface."

Excavations conducted in southern Arizona by the Cyprus Tohono Mine Data Recovery Project, or Cyprus Tohono Project (Lascaux and Roberts 1995a, 1995b; Rieder 1997; Roberts and Ahlstrom 2001), call into question the idea that low-density, low-diversity artifact scatters associated with desert-pavement surfaces can simply be dismissed as surface manifestations with no potential for subsurface cultural remains. Whatever the time scale for the formation of desert pavements over broad areas, the Cyprus Tohono data indicate that small areas of pavement can "heal" over intervals of time and space that are relevant to the interpretation of the Arid West's archaeological sites and features, including those of the ceramic period. We did not arrive at this conclusion until after the Cyprus Tohono fieldwork had been completed. The relevant data were collected through broad-scale mechanical stripping, which, unfortunately, also destroyed geomorphic relationships that, in retrospect, we would like to have studied. In addition, systematic data were not collected on the amount or location of rock-varnish coatings on the stones incorporated in the desert pavement, so this important aspect of desert-pavement formation is mentioned only in passing. Though these data gaps may detract from our findings, they do not invalidate them.

### DESERT PAVEMENT STUDIES

The relationship between cultural features and desert pavement can be understood only in the context of geomorphological research in desert areas (Bull 1991; Cooke 1970; Symmons and Hemming 1968), particularly that conducted in the Mojave Desert (Anderson 1999; Dorn 1988; Haff and Werner 1996; McDonald, McFadden, and Wells 1995; McFadden, Ritter, and Wells 1989; McFadden, Wells, and Jercinovich 1987; Shlemon 1978; Wells, McFadden, and Dohrenwend 1987; Wells et al. 1994; Williams and Zimbelman 1994) and in the adjacent, western-Arizona portion of the Sonoran Desert (Péwé 1978:23-25). Three related questions arising from this research are particularly relevant to our archaeological

problem: how do pavements form in arid environments, how do pavements "heal" once they have been disturbed, and how long does it take for these natural processes to occur? These questions have no simple answers, as a review of the above-referenced sources would show.

There are at least three explanations for the development of desert pavement. (1) What could be called the "erosion" theory holds that wind, and possibly sheetflooding, removes the fine sediment from the ground surface, leaving the pavement as a pebble lag deposit (Cooke 1970:561-562, 569-571; Hayden 1965:273, 1976:275-277; Rogers 1966:39-43; Symmons and Hemming 1968). The erosion theory has been used to explain both the initial formation of desert pavement and the healing over of pavement in areas from which the pebbles have been cleared (Haff and Werner 1996:44). This is the "traditional" explanation (Waters 1992:205), so much so that it has been incorporated in the American Geological Institute's definition of desert pavement (Bates and Jackson 1984:134-135). In spite of this cachet, the erosion theory has, to a considerable extent, been displaced by other explanations over the last couple decades. The erosion mechanism has not been discarded from interpretations of desert pavement, however, as indicated by its recent inclusion in a model to explain the formation of pavement on top of an eolian deposit (McAuliffe and McDonald 1995:61-62). (2) According to the "rising to the surface" theory, alternate wetting and drying of the sediment column leads to the swelling and shrinking of clay, which in turn causes pebbles that are present in the sediment to move upward to the ground surface (Cooke 1970:572; Springer 1958). (3) The most recent explanation, the "born at the surface" or "accretionary" theory, argues that the pebbles making up a desert pavement are created at the ground surface through the disintegration of exposed rocks and then "float" on fine-grained sediment that originates from the local "dust flux." This material accumulates between the pebbles, works its way under them, and eventually forms a layer that slowly thickens beneath them (Anderson 1999; McDonald,

McFadden, and Wells 1995:35; McFadden, Wells, and Jercinovich 1987; Williams and Zimbelman 1994). Supporters of the accretionary theory argue that a period of increased aridity and eolian activity in the mid-Holocene (ca. 8000-4000 B.P.) increased the dust flux in the Mojave Desert. This, in turn, quickened the rate of accumulation of fine-grained sediment beneath desert-pavement surfaces (Anderson 1999:40-41, 107-108, 112). Considering the research effort that it has engendered in recent years, as well its fit with observational data, the accretionary theory must be considered the current "leading explanation" for the formation of desert pavement. Still, more than one of the three mechanisms may have contributed to the development of any given desert-pavement surface, with the relative importance of the mechanisms shifting over time, particularly in response to climatic change (Anderson 1999; Cooke 1970:576-577; Hayden 1976; Wells, McFadden, and Dohrenwend 1987).

### CYPRUS TOHONO PROJECT

The Cyprus Tohono Project Area is located in the Papaguería, a region that stretches over extreme southwestern Arizona and northwestern Sonora (Fig. 1). The project area lies near the settlement of North Komelik, in the Sif Oidak District of the Tohono O'odham Nation. It abuts, and partially overlaps, the Hecla Project Area, which in the 1970s was the scene of a series of archaeological investigations directed by Albert Goodyear and Alfred Dittert of Arizona State University (Goodyear 1975; Goodyear and Dittert 1973). The sites in the two project areas are similar, typically consisting of low-density artifact scatters that often measure more than 100 m. across and that include a variety of surface features, such as small rock rings (Fig. 2), rock scatters, rock clusters, and cleared areas in the desert pavement.

In designing the Hecla research, Goodyear drew on ethnographic accounts of Tohono O'odham subsistence to define six procurement subsystems: bud-flower (i.e., cholla buds), saguaro fruit, prickly pear fruit, leguminous seed

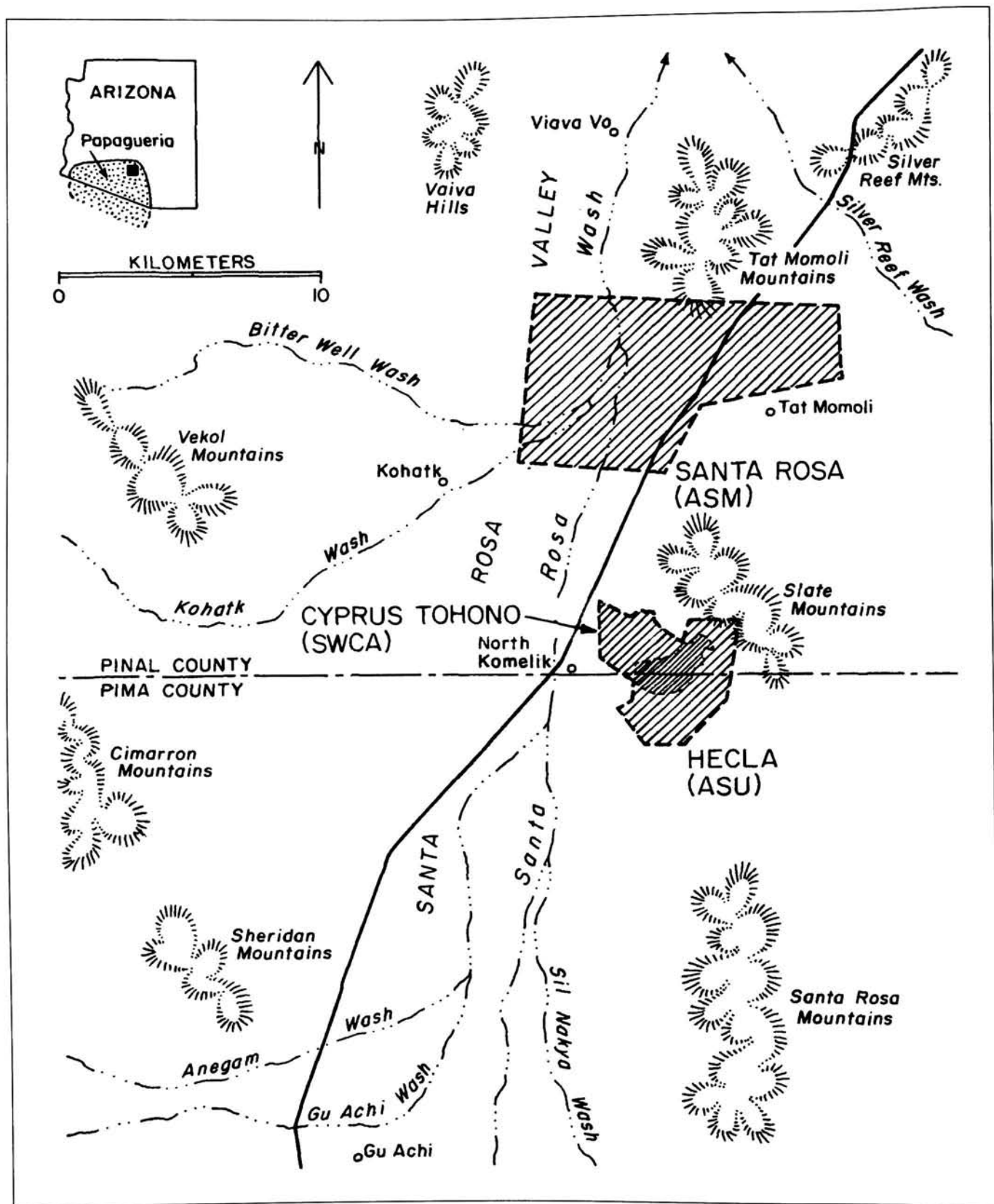


Fig. 1. Map showing the location of the Hecla and Cyprus Tohono project areas.



(i.e., mesquite), organ pipe cactus fruit, and wood. Based on the ethnographic accounts, and taking site-formation processes into account (McGuire 1982:465), Goodyear attempted to identify archaeological correlates, involving both artifacts and features, for each of these subsystems. In doing so, he assumed that the Hecla sites were primarily surface manifestations and that subsurface deposits were generally not present—or if they were present, they would be recognizable on the surface. At about this same time, the Santa Rosa Wash Project was making similar assumptions about bajada sites located a few miles to the north of the Hecla Project Area (Fig. 1) (Raab 1976).

In the mid-1990s, SWCA, Inc. Environmental Consultants returned to the location of the Hecla Project Area to conduct archaeological survey and then data recovery for the Cyprus Tohono Project (Lascaux and Roberts 1995a, 1995b; Roberts and Ahlstrom 2001). A primary objective of our Cyprus Tohono investigations was to verify Goodyear's findings concerning the saguaro-fruit subsystem (Lascaux and Roberts 1995b). In particular, we wanted to explore the architectural history of ramadas, the rectangular, open-walled structures that provide shade and shelter at modern and historic Tohono O'odham saguaro-harvesting camps. Ramadas dating to the late Historical period had been recorded during the Hecla Project (Bruder 1975, 1977; Roberts and Ahlstrom 2001), but, to our knowledge, no prehistoric examples of this kind of structure had been documented in the Papaguería. Because large, heavy posts like those used in Historical period ramadas would have been more difficult to cut down and transport prior to the introduction of metal axes and horse-drawn wagons, we suspected that the prehistoric equivalent might have been a less substantial construction. Therefore, we needed to look for both large and small postholes as possible evidence of ramadas. To do so, we planned to strip broad areas within sites using a backhoe with a 7-foot-wide, sharpened blade that had been developed for just this purpose. With this tool, an experienced operator can remove the soil a few centimeters at a time, exposing in plan

view areas of charcoal or organic staining. The method works best on fine-grained sediments, dominated by sand, silt, or clay, and on cultural features that incorporate few rocks.

The findings of both the Hecla and Cyprus Tohono projects can be discussed with reference to a chronology consisting of four time intervals: the early pre-Classic period (A.D. 550-875), the Vamori phase of the pre-Classic period (A.D. 875-1150), the Sells phase of the Classic period (A.D. 1150-1500), and the Historical period (A.D. 1540-1945) (Ahlstrom, Chenault, and Wroblewski 2000).

### THE PROJECT AREA

The Cyprus Tohono and Hecla project areas are located on the east side of Santa Rosa Valley, on the middle and upper parts of alluvial fans that emanate from the Slate Mountains and extend to Santa Rosa Wash (Fig. 1). Adjacent portions of the foothills of the Slate Mountains are included as well. The eastern, higher-elevation half of the Cyprus Tohono Project Area is dominated by alluvial fans with inactive surfaces that exhibit well-developed, strongly varnished desert pavements (Fig. 2) and that are incised to depths of more than 50 cm. by



Fig. 2. Photograph of a rock ring at Site AZ AA:5:174 (ASM), providing a close-up of desert pavement; such features probably served as rests for collecting baskets (Goodyear 1975:109-110).

ephemeral drainages. Soils contain 5YR argillic horizons overlying thick, well-cemented calcic horizons with Stage II-IV morphology (Machette 1985). These alluvial-fan surfaces correlate with Q2b and Q2c alluvial fans in the Lower Colorado River Valley (Bull 1991) and Ma2 alluvial fans in the Phoenix Basin and are probably 10,000 to 200,000 years old (Huckleberry 1994; Pearthree and Huckleberry 1994). This geomorphological interpretation, which was developed by Huckleberry (Huckleberry and Ahlstrom 1995) during the project's survey phase, indicated to us that there was little potential for the presence of buried cultural materials at sites in this portion of the project area. An exception to this generalization involved areas of recognizably recent deposition, indicated in two settings where desert pavement was absent: (1) shallow (<20 cm. deep) swales and (2) low mounds that had built up around some shrubs, particularly creosote bushes.

The western, lower-elevation half of the Cyprus Tohono Project Area is dominated by active geologic surfaces that are not entrenched. The drainages in this area tend to have distributary plan-view forms. Other diagnostic characteristics are distinct bar-and-swale topography and variation in desert-pavement formation from weakly developed, varnished pavement to absence of such pavement. These active surfaces correlate with Q3 and Q4 in the Lower Colorado Valley (Bull 1991) and Ya1 in the Phoenix Basin and are less than 10,000 years old (Huckleberry 1994; Pearthree and Huckleberry 1994). Again, this geomorphic interpretation preceded data recovery (Huckleberry and Ahlstrom 1995). It suggested that sites in this portion of the project area might contain buried cultural materials, though not in areas covered by desert pavement.

## RESULTS OF SUBSURFACE INVESTIGATION

A combination of hand excavation and mechanical surface stripping was carried out at eight sites investigated during the Cyprus Tohono Project. These sites were artifact scatters, often with artifact concentrations and rock features,

which might have been camps for harvesting saguaro fruit or the products of other kinds of cactus. Hand excavation units were placed within surface artifact concentrations or irregularities in the ground surface, such as areas in the desert pavement that appeared to have been cleared of stones. Areas selected for mechanical stripping included patches of alluvial or eolian fine sand and desert-pavement surfaces that exhibited areas of disturbance (clearings) or surface-artifact concentrations. Features exposed during mechanical stripping were subsequently excavated by hand. A total area of 2,370 m<sup>2</sup> was surface stripped at the eight sites. As a result of this effort, 23 thermal features, four occupation surfaces, one pit structure, and one refuse deposit were identified. All but one of the occupation surfaces, the refuse deposit, the pit structure, and some of the thermal features were buried under fine eolian or alluvial sand in rills or sandy areas adjacent to desert-pavement surfaces. One of the occupation surfaces and one of the thermal features were found under cleared circles. The remaining thermal features were buried under desert pavement.

We discuss three sites that yielded features buried beneath cleared circles or desert pavement: the Quiput site (AZ AA:5:145 [ASM]), the Rabbit-Drive site (AZ AA:5:164 [ASM]), and the Mixed Component site (AZ AA:5:177 [ASM]) (Roberts and Ahlstrom 2001). The Rabbit-Drive



*Fig. 3. Photograph of the Feature 4 complex at the Mixed Component site prior to excavation (reproduced with the permission of the Arizona State Museum, University of Arizona).*

site was in the portion of the project area dominated by active geologic surfaces, though desert pavement was present on the site itself. The two other sites were in the area dominated by inactive surfaces. The sites are discussed in order from most recent to oldest.

### **Mixed Component Site**

The Mixed Component site dated to the Historical period and to the Classic period Sells phase (A.D. 1150-1500), though only the historic component is of interest here (Roberts, Lascaux, and Ahlstrom 2001). Surface evidence at the Mixed Component site included a scatter of flaked-lithic, ceramic, and ground-stone artifacts, four small rock rings, several rock clusters and rock piles, and two cleared areas in the desert pavement. Each of the cleared areas was surrounded by a low berm and was interpreted during survey as a possible ramada. The site was located on a low ridge to the south of a deeply incised drainage, and much of the site area was covered with desert pavement.

Excavation of a 1 m. x 2 m. unit in one of the cleared areas (Feature 3) failed to indicate if it was natural or cultural in origin. The other clearing, Feature 4, proved to be at the center of a feature complex that also included Features 2, 8, 12, and 13. Features 2 and 8 were fire-cracked-rock clusters that were located on either side of the clearing (Figs. 3 and 4). Excavation showed that the rocks were underlain by shallow deposits that, in the case of Feature 2, contained charcoal and ash and, in the case of Feature 8, charcoal flecks and a burned rodent bone. A 1 m. x 4 m. unit was excavated to a depth of 10 cm. in the cleared area itself (Feature 4) but failed to uncover buried cultural remains. Subsequent mechanical stripping of the area showed that the clearing overlay two thermal features, a hearth or roasting pit (Feature 12) and an ash deposit (Feature 13). The hand-excavated unit had overlain the pit feature, but was not carried deep enough to expose it. The ash deposit probably represented material that had been cleaned out of the hearth or roasting pit, and, since neither of the nearby rock clusters was associated with a clearly defined pit, they may have had a similar

origin. Two pieces of evidence date the Feature 4 complex to the Historical period: (1) the presence, in the vicinity, of historic O'odham ceramics and (2) a radiocarbon date of  $150 \pm 60$  B.P., with a 2-sigma calibrated date range of A.D. 1650-1950, on a sample from the ash deposit (Roberts and Ahlstrom 2001:Appendix B). (According to Taylor [1987:35-36; 1988], any radiocarbon value of  $300 \pm 100$  years or less can at best be assigned a calendar age covering the entire 300-year interval from A.D. 1650 to 1950.)

### **Quiput Site**

The Quiput site dated to the pre-Classic period Vamori phase (A.D. 875-1150) and, in the case of the portion of the site that is of interest here, probably earlier in the pre-Classic period as well (ca. A.D. 640-875). It was a large artifact scatter located immediately south of an entrenched wash (Roberts and Lascaux 2001). The ground surface across the site consisted of areas of desert pavement interspersed with areas of loose silty sand located along small rills and shallow drainages. The site possessed multiple artifact classes including ceramics, ground stone, flaked stone, shell, and modern saguaro-fruit-gathering sticks (quiputs) that had been cached in two shallow drainages. Surface features included rock rings, rock clusters, and four cleared areas in the desert pavement. The latter appeared as areas from which the covering of pebbles had been removed and then mounded around the exterior.

Mechanical stripping in a shallow, sandy drainage at the northern edge of the site uncovered a pit structure, the only habitation feature encountered during data recovery for the Cyprus Tohono Project. Ceramics from the pit structure indicated an occupation date during the Vamori phase (A.D. 875-1150). Both hand and mechanical excavation were used to investigate the four clearings in the desert pavement. Two of these clearings, Features 1 and 2, were circular and were located in the vicinity of the site's main artifact and feature concentrations. The other two cleared areas, which were only tentatively identified as cultural and were therefore not given feature numbers,



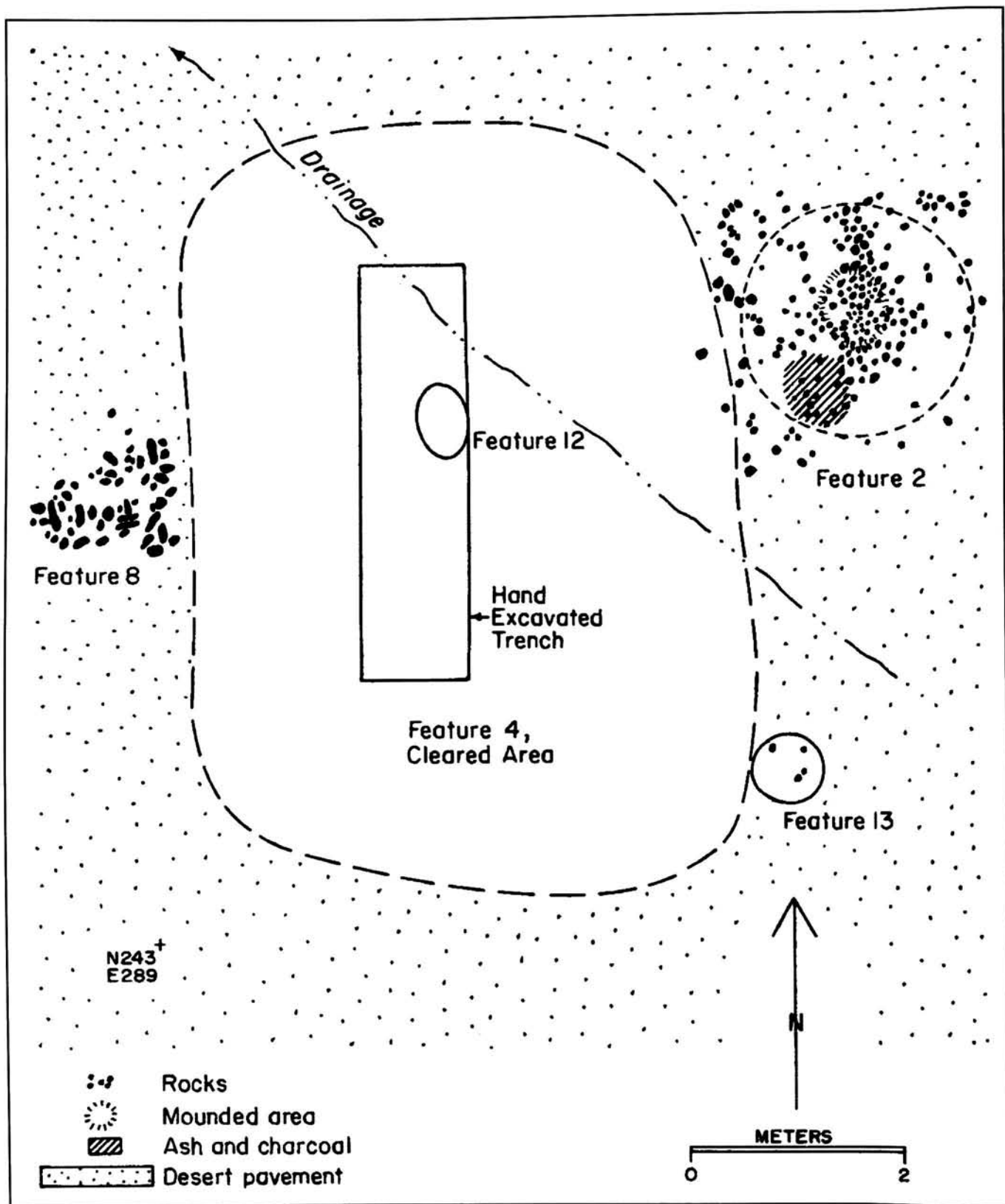


Fig. 4. Map of the Feature 4 complex at the Mixed Component site.

were irregularly shaped and lacked associated artifacts. Only one of the four cleared areas, Feature 2, contained buried cultural deposits.

On the ground surface, Feature 2 measured 2.75 m. x 2.50 m (Figs. 5 and 6). A 1 m. x 2 m. test unit was placed in the center of the feature and excavated to 10 cm. below the ground surface. At this depth, an occupation surface became visible in the eastern half of the unit (Fig. 6). Its presence was indicated by flat-lying artifacts and small cobbles, and by a thin ash lens underlain by oxidized soil—which may have been a shallow thermal feature. At this point, the excavation unit was extended north, south, and east to determine the limits of the feature. The occupation surface was found to extend beyond the cleared area and, in particular, ca. 0.5 m. out under the desert pavement. The surface measured 1.75 m. x 2 m., though additional charcoal and charcoal staining that were identified during subsequent mechanical stripping in the vicinity of the feature suggests it may have been larger than this.

A wood-charcoal sample recovered during hand excavation of Feature 2 produced a radiocarbon date of 1,310 ± 60 B.P., equaling a 2-sigma calibrated date of A.D. 640-875. Although this is the most likely interval when the feature was used, an alternative interpretation should also be mentioned. It is possible that the occupation surface was contemporaneous with the Vamori phase (A.D. 875-1150) pithouse located some 30 m away and that the radiocarbon date came from “old wood” (Schiffer 1987:308-312).

### Rabbit-Drive Site

The Rabbit Drive site dated to the pre-Vamori portion of the pre-Classic period (ca. A.D. 550-775). It was both the oldest site investigated by the Cyprus Tohono Project and the one with the largest number of features buried under desert pavement (Roberts and Lascaux 2001). The site was recorded during survey as a moderately dense scatter of more than 200 prehistoric plainware sherds, more than 50 flaked-stone artifacts, and one vesicular basalt mano fragment. The site was located on a low, desert-



Fig. 5. Photograph of Feature 2 at the Quiput site prior to excavation.

pavement-covered ridge just north of an alluvial flat. The ground surface in the center of the site, where the highest concentration of ceramics was found, consisted of alluvial silt and fine sand with some pebbles. This area, which was crossed by a shallow rill and which measured less than 10 m<sup>2</sup>, was surrounded by loosely consolidated desert pavement (Fig. 7, showing the approximate boundary of the desert pavement).

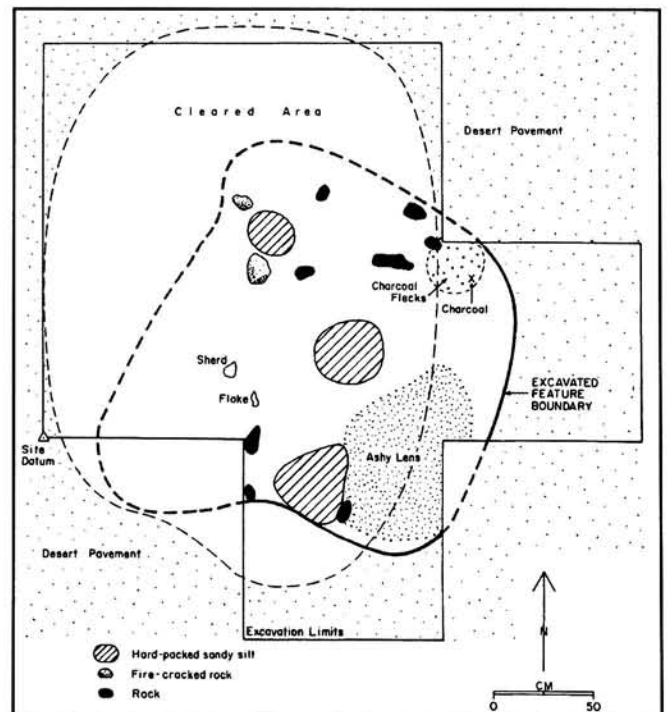


Fig. 6. Map of Feature 2 at the Quiput site.

With the exception of a trail, which consisted of a slightly depressed, 30-50 cm. wide clearing of the pebble cover, no surface features were apparent. Most of the ceramics were located in the sandy swale between the areas of pavement.

The original plan for data recovery had been to place backhoe trenches through the sandy swale in the center of the site. Because the mechanical stripping technique was revealing small thermal features at other sites in the project area, this method, rather than traditional backhoe trenching, was used. An area amounting to roughly 380 m<sup>2</sup> was mechanically stripped to a depth of about 5-10 cm. Twelve features were uncovered through this process (Fig. 7). They included 10 thermal pits, one occupation surface, and one refuse deposit. Seven of the thermal features, including Nos. 1-4, 8, 10, and 12, were buried under the desert-pavement surface.

The thermal features were shallow basins ranging from 40 to 125 cm. in diameter and, in most cases, from 10 to 20 cm. deep. They contained charcoal, small quantities of thermally altered rock, and ash. A number of the features also contained rabbit bones: a minimum of 21 rabbits, mostly jack rabbits, were represented (Chapin-Pyritz 2001). Based on the large number of rabbits, the artifact assemblage, and the arrangement of the roasting features around a central activity area, we have interpreted this site as a camping locale associated with a communal jack-rabbit hunt. A charred pine nut from one of the thermal pits (Feature 3) that lay beneath the desert pavement yielded a radiocarbon date of 1,400 ± 70 B.P., or a calibrated date of A.D. 550-775 (Roberts and Ahlstrom 2001:Appendix B). The identification of possible Vahki Plain ceramics and a few Hohokam Buff Ware sherds from the site is consistent with this radiocarbon date (Gregonis 2001).

### Summary

Disturbance to the desert pavement, marking the location of subsurface cultural remains, was most evident at the most recent site, Mixed Component. At this site, there was a level, cleared area with slightly raised edges and

slightly mounded piles of small rocks, some thermally altered, located adjacent to the clearing—the Feature 4 complex (Fig. 4). At the Quiput site, the disturbances to the desert pavement were barely visible and consisted of small circular areas from which the surface pebbles appeared to have been removed (Fig. 5). Finally, at the Rabbit-Drive site, which was the oldest site in the group, a pavement surface that appeared undisturbed was found to overlie seven thermal features. Nearby were similar subsurface features that were not covered by desert pavement.

All of the cleared areas recorded at the sites selected for data recovery were investigated, but only a small percentage of these areas contained subsurface cultural materials. We had expected the cleared areas to mark the locations of ramadas. However, since patterned postholes, floor surfaces, or other architectural elements were not identified at any of the cleared areas, we could not demonstrate that these features served this function. What we did find was that two of the cleared areas—one at the Mixed Component site and the other at the Quiput site—overlay thermal features. At the Mixed Component site, there was a feature complex (Fig. 4) consisting of the thermal feature, an occupation surface around the feature, and refuse from the feature that included an ash deposit and two concentrations of thermally

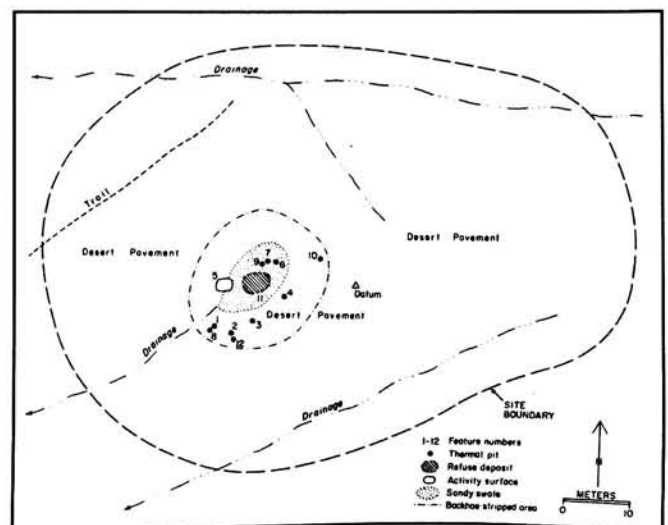


Fig. 7. Map of the Rabbit-Drive site.

altered rock associated with charcoal, ash, and burned bone. At the Quiput site, there was a possible thermal feature associated with an occupation surface (Fig. 6). These two cases suggest that some clearings in desert pavement resulted from use and reuse of thermal features. It is also possible that they were work-areas around hearths or that they mark the locations of ephemeral structures like O'dham brush shelters or kitchens (Roberts and Gregonis 1996).

### OTHER STUDIES

The Cyprus Tohono Project is by no means unique in producing data that bear on the relationship between archaeological sites and desert pavement. There are, for example, at least two other instances in which the excavation of cleared circles or rock rings has produced subsurface evidence of archaeological features. In 1975, David Ferraro of the Nevada Archaeological Survey, University of Nevada, Las Vegas conducted excavations at several sites located along Las Vegas Wash in the southeastern corner of the Las Vegas Valley. Reports on that work, which are incomplete and poorly known (Roberts and Ahlstrom 2000), indicate that it included the investigation of a cleared circle with some rocks in association at Site 26CK1138. Excavation of Feature 1 "produced scattered charcoal in some locations and small deposits of actual charcoal in several loci in an area of fifty centimeters in diameter.... The soil underneath this deposit was slightly redder in color than the surrounding soil" (Ferraro 1975:31-34, also Figs. 7-10; Roberts and Ahlstrom 2000:79, also Figs. 4.18-4.21). The feature was interpreted as a "possible hearth." In the second, more recent study, SWCA, Inc. Environmental Consultants excavated a rock-ring feature on the Barry M. Goldwater Air Force Range in southwestern Arizona (Tucker, Holloway, and Lyon 2000). Feature 1 at Site AZ Y:12:64 consisted of a semicircular rock alignment with a diameter of 1.75 m. The ground surface around the feature was covered with pebbles, and this incipient desert pavement appears to have been about as

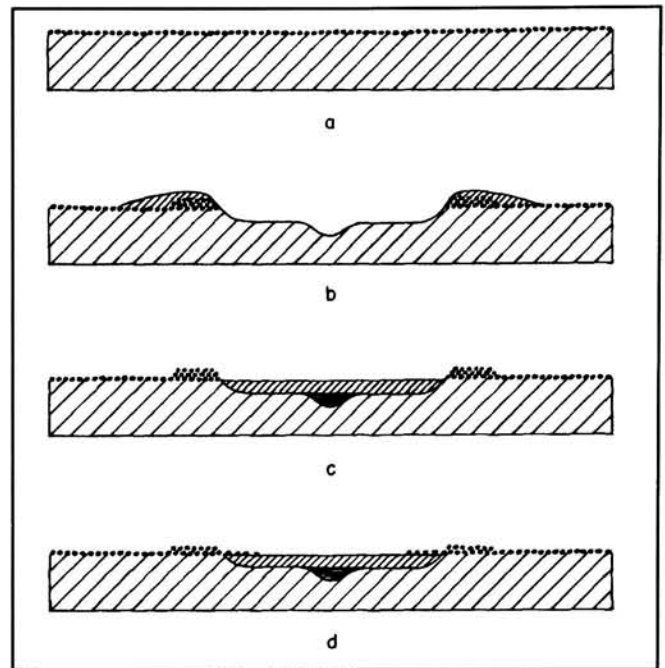


Fig. 8. Hypothesized sequence of desert-pavement healing: (a) intact pavement overlying silty sediment; (b) depression dug through pavement and underlying sediment, with thermal feature in center and berms of material removed from depression—sediment over pebbles; (c) abandoned feature containing cultural fill, depression filled with silty sediment; (d) pebbles have begun moving in over sediment from edge of clearing.

well developed within the alignment as outside it (Tucker, Holloway, and Lyon 2000:Fig. 9.8; David Tucker, personal communication 2000). Excavation of the feature revealed a roasting pit that contained many rocks in its fill, but that was also lined with rocks—the rocks that were visible on the surface had been part of this lining. A sample of wood charcoal from feature fill produced a radiocarbon date of 4480 ± 40 B.P., corresponding to a 2-sigma calibrated date range of 3340-3025 B.C. and 2970-2940 B.C. (Tucker 2000:Appendix E).

Also worth mentioning here is Hunt's (1960:177-185) identification and excavation of six pits in Death Valley that were used to store mesquite pods. It is true that Hunt's features were distinct from the cleared circles and rock rings that are being discussed in this paper. For one thing, they had a recognizable central pit, and for another, the pit was surrounded by a substantial berm of rocks and gravel. Perhaps



over time, however, the pit would fill and the berm would erode sufficiently for the feature to appear as a cleared circle. In support of this possibility, we note that one of Hunt's storage pits may not have been associated with a berm (Hunt 1960:Fig. 50). Also, three of her storage pits that did have berms contained perishable materials (mesquite pods, a grass lining, or wooden artifacts), which would suggest, even considering the sites' extremely arid setting, that the features were not of great antiquity.

Two sites, both dating to late Pleistocene/early Holocene times, provide evidence for the recovery of artifacts from beneath desert pavement. In 1965, Davis and True (Davis 1970) excavated several units at Iny-20, a Paleoindian site located in the Panamint Valley of southern California. Digging of the units began with the removal of "the pebble pavement." Pieces of flaked-lithic debitage, points/knives, and fragments of animal bone "were concentrated between 3 inch and 18 inch levels and disappeared at 24 inches. No difference in artifact types or numbers was noted between upper and lower levels. That is, the deposit seemed to be a cultural unit. It is possible that both artifacts and gravels gradually washed down from the ridge just above, and remained in place after the...fan soils began to form.... [That is,] the deposits may be secondary (redeposited)" (Davis 1970:110). [Davis and True had begun their work at Iny-20 in 1964, with the digging of three test units. In describing Pit 2, which contained buried artifacts, Davis (1970:90) referred to a surface covered by "a thin scatter of angular dolomite gravel." We assume that this was different from the "desert pavement" found on the surface of the units excavated in 1965.]

Dames & Moore, Inc. excavated the second site in the early 1990s as part of the Kern River Gas Transmission Project. The site, CA-SBR-6566, was located on the northwest side of Silver Lake, in the East Mojave Desert (Apple and York 1993; also Cleland 1996). It occupied the toe of an alluvial fan and dated to the Lake Mojave period, specifically to 10,500-8500 B.P. Flaked-lithic artifacts were found on, in, and underneath a well-developed desert-pavement surface.

Artifacts were recovered from 70-80 cm. below the ground surface in three of the 13 (1 m. x 1 m. and 1 m. x 2 m.) units that were excavated at the site. In a discussion of "Geomorphology and Geochronology," to which W. G. Spaulding contributed, the excavators argued that the vertical distribution of artifacts at CA-SBR-6566 could best be explained with reference to the accretionary model of desert-pavement formation. In particular, "it would explain the presence of artifacts at depth and at the surface; elevation of the pavement surface would be an incomplete process and clasts (cultural and otherwise) would be left behind at various depths in the sediment column during accretion" (Apple, York, and Spaulding 1993:120). They argued that a moderately indurated stratum of cobbles and gravel that was encountered at a depth of 50 cm. in most of their excavation units might have represented the ground surface when the site was occupied. This would mean that 50 cm. of fine-grained sediment had accumulated beneath the desert pavement in the last 10,500 to 8,500 years. They noted further that this figure would be consistent with the 75 cm. of accumulation that, by Wells's (1992) estimate, had occurred in the last 13,500-10,500 years at the "nearby" El Capitan Beach Ridge complex. These two cases suggest an average rate of accumulation on the order of 5-7 cm. per 1,000 years (Apple, York, and Spaulding 1993).

Other data, suggesting a somewhat slower rate for the elevation of desert-pavement surfaces by the accretionary process, also exist. The evidence comes from studies of alluvial fans in the Mojave Desert, and it involves the relationship between the estimated ages of alluvial fans and the thickness of the Av horizons that underlie desert-pavement surfaces that are located on those fans (McDonald, McFadden, and Wells's 1995:39, Fig. 3b; Anderson 1999:Tables 20 and 21). If one assumes that the amount of accumulation is more or less equal to the thickness of the Av horizon, then these data suggest that the desert pavement surfaces in this area rose at a rate of no more than a centimeter or two per 1,000 years.

There is archaeological evidence relating to

the healing-over of desert pavement on archaeological sites. The regeneration of the pebble cover within Feature 1 at AZ Y:12:64 has already been mentioned. In another case, Holmlund (1993) relied on impressionistic evidence in the tentative dating of geoglyphs found along the Lower Colorado River. Geoglyphs, also known as intaglios, are large ground figures consisting of paths from which the desert pavement has been cleared. Holmlund referred to evidence that some figures had recognizably "faded" over a period of some 40 years; this suggested to him that "the figures are surely less than 1,000 years old and probably less than 500 years old" (Holmlund 1993:101).

Marmaduke and Dosh (1994:100-145) employed more systematic data in their study of cleared circles located on the Yuma Proving Ground in southwestern Arizona. These data included (1) feature morphology, (2) the size distribution of surface pebbles along transects extending from the outside to the center of individual clearings, as well as in areas of undisturbed desert pavement, and (3) indirect associations, involving propinquity, between mostly surface occurrences of dated Patayan potsherds (Waters 1982) and particular categories of cleared circles. Based on this and other evidence, Marmaduke and Dosh (1994) concluded that cleared circles are gradually obliterated by the lateral movement of pebbles into the clearing from the outside. In their words, "rather than new gravels being exposed from below to become patinated and varnished over a long period of time, old and already patinated and varnished gravels moved laterally to fill voids in the fabric of the local pavement left by the clearing of the circles" (Marmaduke and Dosh 1994:100). Marmaduke and Dosh also produced "first approximation" rates for the re-establishment of desert pavement within cleared circles (Table 1). We will return to these estimated rates later on.

Also relevant to our topic is Haff and Werner's (1996) geological study of how disturbed areas of desert pavement heal. Fieldwork took place in the Panamint Valley of southern California and involved the removal of surface pebbles from

experimental plats ranging in size from 5 to 40 cm. square, followed by the detailed recording of pavement regeneration over a 5-year period. Data collection included the measurement of pebble sizes and the tracking, on close-up repeat photographs, of the movement of individual pebbles. Haff and Werner concluded that surface scars heal through the displacement of pebbles from around a clearing in the pavement into that clearing. Additional findings of their study are integrated in the following discussion.

Marmaduke and Dosh and Haff and Werner, reached the same conclusion, that scars in a desert pavement heal from the edges inward. They also collected comparable data on the nature of the stones that move into the clearing. Marmaduke and Dosh (1994:103-113) documented a decrease in the weight and size of pebbles along transects from the outside to the inside of cleared circles. Haff and Werner (1996:40) found that the pebbles displaced into their study plats were smaller than the pebbles in the surrounding pavement. This size grading could contribute to a clearing's continued visibility even after it has healed over with desert pavement. Of greater importance to this visibility would probably be the lighter color of the pebbles in the healed area—they would not have been in place long enough to become as varnished on their upper surfaces as the pebbles in the surrounding pavement. Eventually, however, larger pebbles move in, the degree of varnishing increases, and the clearing disappears from view (Marmaduke and Dosh 1994:113). Unlike

**Table 1**  
**ESTIMATED CLEARED-CIRCLE INFILL RATES**

Infill Range (m.)	Date Range (A.D.)
.00-.22	1700-1900
.23-.42	1500-1700
.43-.71	1200-1500
.72-.91	1000-1200
.92-1.20	700-1000

Note: data from Marmaduke and Dosh (1994:Table 4.11)

Marmaduke and Dosh (1994) and Haff and Werner (1996), Péwé (1978:24) has argued that pavement regenerates over small clearings in the same manner that it formed in the first place, that is, by means of either the "erosion" or the "rising to the surface" mechanisms identified earlier.

## DISCUSSION

The discovery of archaeological remains beneath desert pavement, specifically by the Cyprus Tohono Project but also in the other cases mentioned, has implications for the geomorphic study of desert pavement, for the prehistory of the Papaguería, and for the evaluation of site significance in desert areas.

### Desert Pavement Studies

Evidence from the Cyprus Tohono and other sites bear specifically on the process whereby small areas of disturbed desert pavement fill in and heal over.

(1) The subsurface features that were associated with desert pavement at the Cyprus Tohono sites were overlain by 5-10 cm. of silty sediment. This is true of the features located under clearings in the desert pavement, as well as those that were located, either wholly or partially, under desert pavement. If one assumes that the desert pavement has been stable since the time of site occupation, it follows that either the site's inhabitants located their occupation surfaces and pit features in existing depressions, possibly already cleared of desert pavement, or they created their own depressions by digging down through the pavement and 5-10 cm. of the underlying fine sediment (Fig. 8). The existence of pebble berms around many cleared circles suggests that, in these cases at least, the clearing was man-made.

(2) Since their abandonment, the depressions have received the aforementioned 5-10 cm. of silty sediment (Fig. 8). This is consistent with Hayden's (1976:282-283) identification of "deep type" sleeping circles in the Sierra Pinacate of northwestern Sonora as "silt traps." In addition, the Cyprus Tohono depressions have been at least partially covered by a layer of pebbles. Not

only have both fines and pebbles moved into the depressions, they appear to have done so to desert-pavement specifications—that is, with fine sediment below and a pebble layer above. Haff and Werner's research clarifies the relationship between the sediment and the pebbles. Along with preparing study plats, Haff and Werner removed boulders to produce cavities in areas of otherwise intact pavement. They found that, "as long as cavity walls remain steep, repaving can be temporarily halted or reversed as colluvial infilling of fine material buries the partially repaved cavity bottom" (Haff and Werner 1996:42). Their data suggest the existence of a "flex zone" at the edge of the depression in which a hearth of other feature was placed. In this zone, the fine-grained sediment would be mixed with pebbles that were displaced into the depression, and buried, as the fines gradually filled the depression.

(3) Points (1) and (2) assume that the undisturbed desert-pavement surface located in the vicinity of a buried feature has been stable, with respect to elevation, since the time of feature abandonment. There is another possibility, however. According to the accretionary theory of desert-pavement formation, the surrounding surface would gradually rise as fine sediment accumulated beneath the rock fragments making up the pavement. Could this mechanism explain the vertical difference between the detection level of the buried features and the level of the adjacent desert-pavement surface at the Cyprus Tohono sites? (As opposed to the idea, included in Point 1, that the features were built in either man-made or natural depressions.) The accretionary growth of the Av horizon might have played this role, particularly in the case of the Rabbit-Drive site, which was more than 1,000 years old. The process could also have had a significant effect on the formation processes of older sites, including those dating to the Paleoindian, Lake Mojave, or Archaic periods. This is particularly true of sites that are old enough to have experienced periods of increased aridity, leading to increased rates of Av-horizon growth.



(4) The pavements overlying the Cyprus Tohono features were located on the periphery of cleared circles. Our data suggest that surface pebbles had moved horizontally into the clearings from the outside, causing the pavement to grow inward across the clearings (Fig. 8). This agrees with the conclusions of both Marmaduke and Dosh (1994) and Haff and Werner (1996) concerning the healing of disturbed desert pavement.

(5) The fact that the pavement appears to be growing into the circles on top of the newly deposited silty sediment implies that, for the period covered by the sites in question, the process of sediment deposition has occurred much more rapidly than the lateral growth of the pavement.

(6) What was the source of the silty sediment that filled an existing depression and of the pebbles that contributed to the inward growth of the pavement? Much of the sediment could have been the same material that had been removed to make the depression in the first place, particularly if it had been piled around the clearing (Fig. 8). This material could have been blown or washed into the depression after the feature was abandoned. Additional fine-grained sediment could have come from the regional dust flux, with the important, local augmentation of silty material exposed around the site as a result of damage to the desert pavement caused by the site's inhabitants. This sediment would have been deposited in the depression by the wind.

The best source for the pebbles would have been the berm, or halo, of stones that surrounds many clearings and that was produced when the clearing was first made (Fig. 8). In their study, Haff and Werner prepared two kinds of plats: in one, they placed the pebbles removed from the plat around its edges, forming a berm, and in the other, they deposited the pebbles away from the plat. They found that "the recovery rates of plats lacking a berm are significantly less than for bermed plats" (Haff and Werner 1996:40). What moves the pebbles back into the clearing? Haff and Werner (1996:40-41) present evidence suggesting that "animal activity is one important cause of stone displacement" (1996:38). Another

possible mechanism is sheetflood or sheetwash (Haff and Werner 1996:44; Hayden 1976:282; Williams and Zimbelman 1994). People could have played a role as well, particularly considering that preferred locations were often revisited and reused over long intervals of time. Another mechanism is gravity: Marmaduke and Dosh (1994:100) report that, for a majority of cases (81%, n=48), the extent of infilling was greater in the quadrant where the center of the circle lay downslope from the rim than in the quadrant where it lay upslope from the rim. Gravity is an "underlying" mechanism, in the sense that it would contribute to pebble movement initiated by animals, sheetwash, or people.

(7) We estimate that the processes of sediment deposition and pavement restoration have been operating at the Mixed Component site for 100-400 years, at the Quiput site for 800-1,300 years, and at the Rabbit-Drive site for 1,200-1,400 years. There are corresponding differences among the sites in the lateral growth of the desert pavement—if one accepts the idea that the pavements are advancing inward from the edges of clearings. There appears to have been little horizontal growth in 100-400 years at the Mixed Component site, at least 0.5 m. of growth in 800-1300 years at the Quiput site, and up to 5 m. of growth in 1,200-1,400 years at the Rabbit-Drive site.

These estimates on the rate at which pavement can "heal" can be compared to other observations and data. Hayden (1976:282) identified "shallow type" sleeping circles in the Sierra Pinacate that, although still recognizable, "may be fully paved with outwash cinders and those exposed by deflation, all well varnished." Hayden considered these filled circles to be characteristic of the Malpais Stage, whose end he dated to around 17,000 years ago. This would imply that he considered infilling to be a slow process. At the opposite extreme, Péwé's (1978:24) analysis of purposely cleared, 18 foot by 18 foot study plats located near Quartzsite, Arizona showed that "in 10 or 12 years enough of the fines will be removed to generate an armor similar to [though incorporating somewhat



smaller pebbles than] the original.”

More comparable to the Cyprus Tohono data are Marmaduke and Dosh's (1994:Table 4.11) estimates of desert-pavement infilling rates for cleared circles on the Yuma Proving Ground (Table 1). The Mixed Component site, with little evidence for horizontal growth of the desert pavement, corresponds to Marmaduke and Dosh's infill range of 0.00-0.42 m. In this instance, the dates from the two studies are identical: A.D. 1500-1900 for the Mixed Component site and for a combination of two of Marmaduke and Dosh's infill categories. The Quiput site, with 0.5+ m. of growth, falls within Marmaduke and Dosh's infill range of 0.43-0.71 m. In this case, the site's date is earlier than the infill category's—A.D. 600-1100 as compared to A.D. 1200-1500. In terms of its date, the Quiput site is a better match with Marmaduke and Dosh's next two infill ranges: 0.72-0.91 m., dated to A.D. 1000-1200, and 0.92-1.20 m., dated to A.D. 700-1000. In other words, our data from the Quiput site point to a slower rate of infilling than Marmaduke and Dosh's data. It should be remembered, however, that in the case of the Quiput site the depression beneath the cleared circle had to fill with fine-grained sediment before healing of the desert pavement could properly begin, and this may not have been a factor in the cases studied by Marmaduke and Dosh. Also, the data from the Quiput site represent the minimum amount of infilling; this is because we do not know how large the cleared area was originally, that is, how much farther out it extended than the buried occupation surface.

The situation with the Rabbit-Drive site is more complicated. At face value, the data suggest that there had been up to 5 m. of lateral growth in the desert pavement since the site's occupation, that is, since A.D. 500-700. This greatly exceeds Marmaduke and Dosh's maximum infill range of 0.92-1.20 m., which they date to roughly the same time interval, or A.D. 700-1000. It is also much greater than our estimate of 0.5+ m of lateral growth at the Quiput site, whose date of A.D. 600-1100 is only slightly more recent than the Rabbit-Drive's date of A.D.

500-700. A likely explanation for these discrepancies is that the Rabbit-Drive site originally possessed a number of small, discrete clearings in the desert pavement, one for each hearth or group of proximate hearths. It was these smaller clearings that had filled in entirely with desert pavement in the 1,200-1,400 years since the site was occupied. If so, our estimate of 5 m. refers not to the distance over which the pavement has reformed, but to the width of the zone within which this process had taken place.

Haff and Werner (1996) also studied the rate at which scars in the desert pavement will heal. Based on projections from their 5 years of data, they estimated that one of their 40 cm. x 40 cm. plats would be resurfaced in 80 years. This translates, conservatively, to an infill rate of slightly more than 20 cm. a century. For purposes of comparison, we derived an average infill rate from Marmaduke and Dosh's (1994:Table 4.11) data of somewhat less than 10 cm. a century, or about half the rate indicated by Haff and Werner. The procedures used in deriving each of these rates could be criticized, and neither should be taken too literally. Still, it is worth noting that neither rate is inconsistent with the idea that, in the 1,200 to 1,400 years since the Rabbit Drive site was occupied and abandoned, 1-2 m.-diameter clearings around individual hearths could have disappeared through the healing of desert pavement.

### Culture History

The implications of our findings for the prehistory of the Papaguería have been dealt with elsewhere (Roberts and Ahlstrom 1997, 2001) and will be stated only briefly here. Surface artifact assemblages led Goodyear (1975) and Raab (1976) to the conclusion that the bajadas on the eastern side of the Santa Rosa Valley—which would include most of the Hecla and Cyprus Tohono project areas—saw greater use during the Sells phase of the Classic period and the Historical period than during the pre-Vamori and Vamori phase portions of the pre-Classic period. Ceramics recorded during the Cyprus Tohono survey supported this conclusion. We changed our minds, however, on the basis of the

subsurface cultural remains that were exposed through mechanical surface stripping.

Temporally diagnostic, pre-Classic period artifacts were recovered in all of the environmental zones in the Cyprus Tohono Project Area. The buried pre-Classic period features that were uncovered during surface stripping attest to the fairly extensive and multifunctional use of the area during this time. The single pit structure, most of the occupation surfaces, and many of the thermal features that we found were at pre-Classic period sites. Although informal, the pit structure provides evidence for at least short-term, probably seasonal, habitation in the area. Four of the seven pre-Classic period sites investigated contained shallow thermal features that probably functioned as hearths or shallow roasting pits for processing cactus buds. Maize pollen was found only at sites dating to this period, and three of the four sites with trough metates (possibly used to process maize) were pre-Classic in age. Animal procurement and processing, both of jack rabbits and of larger game, appears to have been an important subsistence pursuit. In addition, all of the exotic marine shell and obsidian that was recovered during data recovery came from pre-Classic period sites.

In comparison, the three sites with the Classic period diagnostics were less widely distributed about the project area than were sites with pre-Classic period artifacts, and all were situated in the area's more upland sections. No structures or occupation surfaces and only two thermal features were encountered at these sites. Decorated potsherds were in fact more abundant on Classic period sites than on pre-Classic ones. The percentage of decorated pottery increased from less than 1% on pre-Classic period sites to 5% on Classic period sites. The smaller percentage of decorated sherds on pre-Classic period sites helped to make those sites less visible, archaeologically, than the later, Classic period ones. The healing of desert pavement may also have lessened the visibility of pre-Classic period activity in the area.

The real difference between Classic and pre-Classic period exploitation of the upper bajada

appears to involve the manner in which it was used rather than the amount of its use. The Classic period saw repeated, but short-term, exploitation of cactus or other resources, as Goodyear (1975) thought. Pre-Classic period use, on the other hand, involved longer-term, though not permanent, habitation with some degree of emphasis on hunting and possibly tending of farm plots. The evidence relating to the existence of both hunting and floodwater-farming subsistence subsystems in the pre-Classic period came entirely from subsurface contexts. It is therefore not surprising, given the Hecla Project's emphasis on surface data, that these subsystems were not included in Goodyear's subsistence framework.

### Determining Site Significance

Much of the archaeological research conducted in the Arid West over the last several decades has been mandated by Section 106 of the National Historic Preservation Act of 1966, as amended. According to the regulations for implementation of Section 106 (to be found in 36 CFR Part 800: Protection of Historic Properties), the act applies to sites that are "included in or eligible for the National Register of Historic Places." All of the sites investigated by the Cyprus Tohono Project, including the three that are discussed in this paper, were determined to be eligible for the National Register on the basis of survey (i.e., surface) data. These decisions concerning eligibility were borne out during data recovery, thanks in particular to the broad-scale, mechanical surface stripping that was performed at the sites. In all, the Cyprus Tohono Project stripped an area of 2,370 m<sup>2</sup> distributed among eight sites. This stripping effort, along with hand excavation, revealed 23 thermal features, 4 occupation surfaces, 1 pit structure, and 1 refuse deposit. Substantial data were also obtained from surface collection of the sites.

The results of the Cyprus Tohono Project's subsurface investigations were certainly gratifying. It is important to realize, however, that the two agencies that oversaw the project—the Bureau of Land Management and Arizona

State Historic Preservation Office—might, under other circumstances, have approved a lesser research effort leading to a more modest outcome. Given that the Cyprus Tohono sites had few surface features (mostly cleared circles and small rock rings that were interpreted as basket rests), had few temporally diagnostic artifacts, and, in most cases, were located in desert-pavement settings, they might have been interpreted as not eligible for the National Register. Or it might have been suggested that the sites could be eligible if significant subsurface remains were present, and that they be tested to determine if this were the case. The surface artifact scatters at the Cyprus Tohono sites were of low enough density and variety to suggest that subsurface habitation structures (i.e., pit houses) were not present. Under these circumstances, it would not have been unusual to limit testing to the hand-excavation of several small (1 m. x 1 m. or 1 m. x 2 m.) units per site. Just such a strategy was applied some years ago to sites, similar to those in the Cyprus Tohono Project Area, that were recorded in west-central Arizona along the Palo Verde to Devers Transmission Line Corridor (Carrico and Quillen 1982). This approach would almost certainly have seriously misjudged the subsurface information potential of a substantial proportion of the Cyprus Tohono sites.

### CONCLUSION

The research on desert pavement and desert-pavement sites that we have described in this paper supports several conclusions.

(1) Significant subsurface cultural remains can be present in desert settings where they are oftentimes not expected—beneath desert pavement, beneath cleared-circle and rock-ring features, and in association with low-density surface artifact scatters.

(2) Once identified, these occurrences have the potential to contribute time-sensitive data, in the form of radiocarbon dates and temporally diagnostic artifacts, that are relevant not just to the archaeological study of prehistory, but to the geomorphological study of desert pavement.

(3) Clearings in desert pavement heal as pebbles are displaced inward from the edges of the clearing. The presence of a berm incorporating the cleared pebbles speeds up the healing process. In the early stages, the displaced pebbles are smaller, on average, than those in the surrounding pavement, and the displaced pebbles become smaller as one moves from the edges to the center of the clearing. Thanks to this size grading, and to the lesser degree of varnishing on the upper surfaces of the displaced pebbles, the clearing could remain visible for a time even after it has healed over with desert pavement. But eventually it would heal over completely.

(4) At the Cyprus Tohono sites, a place was prepared for a hearth or living surface by clearing away not just the desert pavement, but 5-10 cm. of the underlying fine-grained sediment. In these and similar cases, healing would begin with the filling in of the depression with new fine-grained sediment, followed by the reformation of the desert-pavement surface.

(5) Disturbed desert pavement can heal over time scales that are relevant to the study of prehistoric archaeology in the Arid West. Moderately well-developed pavement can reform completely over small features like hearths in just over 1,000 years. Recent studies provide evidence for infilling rates of 10-20 cm per century.

(6) Paleoindian period sites can extend from above the desert pavement to 0.5 m. and more beneath the pavement; the accretionary model of desert-pavement formation may help to explain the vertical distribution of artifacts at some of these sites.

(7) About 10 years ago, the Bureau of Land Management published an influential archaeological overview of the Lower Colorado River region. According to this document, "There appears to be little justification for test excavations of low-density scatters or sites located on desert pavement.... However, subsurface testing should not be written off entirely" (Stone 1991:73). And again, "Although testing [of rock rings] has proven unproductive, it would be unwise to dispense completely with



excavation. If we simply assume the lack of subsurface remains, we will never find those that might exist" (Stone 1991:76). The data reported here indicate that rock rings, cleared circles, and artifact scatters on desert pavement can indeed be associated with subsurface cultural remains, and these data therefore reinforce the overview's caution not to simply write-off, or dispense with excavation at these sites.

In closing, we acknowledge that our research has disturbing implications. For one thing, it suggests that not enough work has been conducted on some sites located in desert-pavement settings. For another, it raises the prospect of small features being distributed unpredictably under broad areas of archaeological site. In addition, our research contradicts the experience of archaeologists who have excavated rock rings and cleared circles, or who have dug units through desert pavement, without result. This experience notwithstanding, we would recommend that archaeologists, as well as government agencies, keep an open mind to the possibility of buried cultural features and deposits being present on desert-pavement sites where they might not previously have been expected. We can also note that mechanical surface stripping provides one, and perhaps the only, cost-effective means of looking for such cultural remains under desert pavement—at least when those remains are shallowly buried, as at the Cyprus Tohono sites. Finally, we can point to the possibility of increasing the research potential of desert-pavement sites that, "on the surface," may appear to have relatively little to tell us about the past.

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