AMS ^{14}C Age Constraints on Geoglyphs in the Lower Colorado River Region, Arizona and California

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Giant ground figures are widespread in the lower Colorado River area of southwestern North America, yet their chronology has remained unconstrained by numerical ages. Thirteen AMS ^{14}C measurements reported here indicate that geoglyphs were made from before ~A.D. 1200 to before ~900 B.C. We account for potential contamination from prior organics in weathering rinds. All other potential errors point to ^{14}C dates being minimum-limiting ages for the manufacturing of geoglyphs. Although these ages indicate considerable chronological complexity among geoglyphs, our data are consistent with the linguistic hypothesis that the Yuman people in the desert of southeastern California migrated from Baja California—rather than from the north. These results must, however, be placed under the cloud of uncertainty that hangs over the entire field of AMS dating of rock art: the untested assumption surrounding contemporeneity of organics in a surface context.

INTRODUCTION

Preliterate desert societies have formed most of the world's "earthen art," a term which is used exclusively to identify two varieties of art fashioned on planar landforms—rock alignments and geoglyphs. The alignment is additive making a positive image when surface boulders are arranged into a design. In contrast, geoglyphs are subtractive in that they are made by scraping away or gathering up the surface cobbles, which are usually darkened by manganiferous rock varnish (Dorn, 1991; Dorn and Oberlander, 1982). The areas of stone removal are much lighter than the surrounding pavement, due to the exposure of the Av soil horizon and exposure of unvarnished cobbles. The "Nazca lines" of Peru (Clarkson, 1990; Reiche, 1968) are classic examples of geoglyphs, although similar forms have long been recognized in North America (Davis and Winslow,

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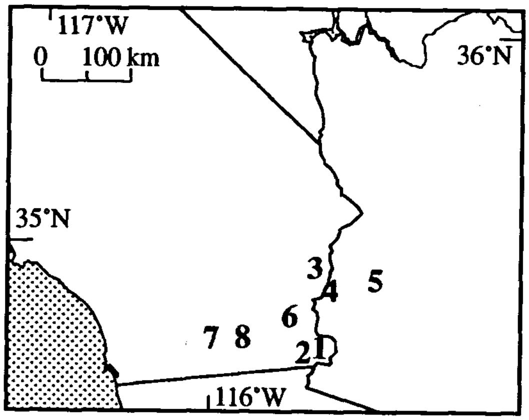


Figure 1. Map of geoglyphs sites, where site numbers correspond to Table I.

1965; Holmlund, 1993; Hunt, 1960; Johnson, 1986; Rogers, 1966; von Werlhof, 1989).

Geoglyphs and rock alignments do not usually occupy the same area. Geoglyphs dominate the fields of earthen art in Peru and Chile (Clarkson, 1990; Reinhard, 1988). Rock alignments, in contrast, comprise most of the earthen art in Australian drylands (Berndt and Berndt, 1965). Along the lower Colorado River of North America, geoglyphs and rock alignments both occur, but rarely side by side on the same desert pavement.

Earthen art comprises a potentially important part of the prehistory of an area, due to the skill and coordination of efforts required in their fabrication, the spatial context, iconography, and potential for cultural interpretations. Although earthen art has been the subject of ongoing study in the Mojave and Sonoran Deserts of southwestern North America (Davis and Winslow, 1965; Hayden, 1976; Holmlund, 1993; Hunt, 1960; Johnson, 1986; Rogers, 1966; von Werlhof, 1986, 1989, 1994), these motifs have been typically ignored by the larger archaeological community working in the region. This may be due to a complex combination of several factors. First, earthen art is not easily detected by the untutored eye, being of large design and on a horizontal surface. Second, it has been difficult to assign a function to these designs (ibid). Lastly, it has not been possible to place earthen art in a chronometric context that can be compared directly to cultural remains in a stratigraphic context—until the widespread use of accelerator mass spectrometry (AMS).

Radiocarbon dating by AMS has led to a revolution in dating rock art in a surficial context. ^{14}C ages are being assigned to milligram quantities of carbon in a wide variety of surficial materials, for example, charcoal paintings (Valladas et al., 1992), bees-wax paintings (Nelson et al., 1992), organics in rock art paint (Chaffee et al., 1993; Russ et al., 1992, 1990), blood (Loy, 1994; Loy et

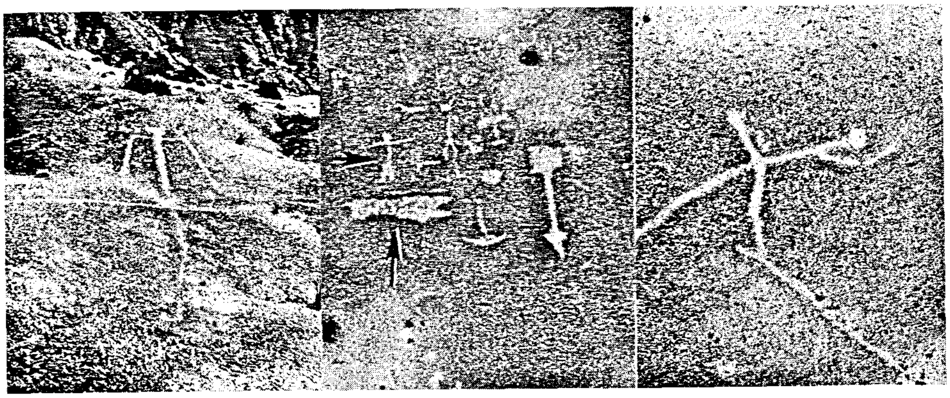


Figure 2. Aerial photographs of selected geoglyphs: Winterhaven stick figure (left), Quartzite figures (middle where arrows point to geoglyphs), and Singer Complex (right). Scale is provided by creosote bushes (*Larrea divaricata*) that are 1–2 m in diameter.

al., 1990), oxalates interbedded with paint (Watchman, 1993a), and organic detritus encapsulated in petroglyphs by rock coatings (Francis et al., 1993; Nobbs and Dorn, 1993).

Organic remains have also been encapsulated by rock varnish formed on top of geoglyphs in Nazca, Peru, and subsequently radiocarbon dated (Dorn et al., 1992). Prior to this study, there have been only three overlapping minimum ^{14}C ages that constrain the antiquity of geoglyphs in North America: A.D. 875–1158, A.D. 668–1152, and A.D. 668–1011 (Dorn et al., 1992). In this article, we present 10 new AMS ^{14}C measurements on geoglyphs, and reanalyze errors associated with the three previous ^{14}C measurements. Our data suggest that the chronological story appears to be considerably more complex than the first results suggested.

STUDY SITES

Our study sites are adjacent to the lower Colorado River in Southwestern North America (Figure 1). Figure 2 displays overhead views of some of the geoglyphs, sampled with permission from the Bureau of Land Management and the Quechan Tribal Council. The particular geoglyphs were selected based on characteristics that would make them suitable for dating (less disturbed, cobbles not washed in from adjacent pavement), and because the nature of the motifs have some potential to inform on prehistoric culture.

This region was selected for this initial study because it contains a large concentration of geoglyphs within the bounds of the southern Yuman tribes, whose cultural history is fairly well known (Alvarez de Williams, 1974; Bee, 1983; Castetter and Bell, 1951; Ezell, 1963; Forde, 1931; Gifford, 1931; Harwell and Kelly, 1983; Kroeber, 1925). Also, this is the most arid region of North

America. Aridity is important because it is correlated with high pH in desert dust, which aids in the stability of the rock coatings that encapsulate the dated organic matter.

METHODS

The method of dating geoglyphs follows Dorn et al. (1992). The model we used to sample geoglyphs assumes the following sequence.

1. Clasts, formerly underneath the surface of a desert pavement, are exposed to the subaerial environment by geoglyph manufacturing.
2. Lichens and other organisms then grew on these clasts, and left remains behind in the weathered rinds of the clasts.
3. Slower growing rock coatings of manganiferous rock varnish grew on the rock surface, encapsulating the organics within the weathering rinds.

The first assumption is reasonable, since the sampled geoglyphs were made by clearing darkly varnished cobbles in desert pavements, which exposed lighter colored silt and unvarnished cobbles (Figure 2). The centimeter-sized clasts observed within the sampled geoglyphs may be: (1) "inherited" from the previous natural desert pavement; (2) exposed by geoglyph manufacturing; or (3) exposed after geoglyph manufacturing by pavement forming processes (Mabbutt, 1979).

The approach used here is to try and select the cobbles exposed by geoglyph manufacturing, based upon field and laboratory characteristics. Clasts inherited from natural pavements adjacent to the geoglyphs were avoided by not collecting well-varnished clasts, by sampling the widest sections of the geoglyphs, and by selecting clasts with calcrete rinds which would indicate a former subsurface position for the clasts. Forty cobbles with only patches of varnish were collected.

It is impossible to distinguish in the field which of these cobbles were exposed by geoglyph manufacturing from those exposed later, by pavement-forming processes (Mabbutt, 1979). Therefore, rock varnish cation ratios were to establish a *relative* age sequence, following the conclusion of several independent research groups that the cation ratio of (K + Ca)/Ti decreases over time (Bull, 1991; Dorn, 1983; Glazovskiy, 1985; Pineda et al., 1988; Whitney and Harrington, 1993; Zhang et al., 1990) due to greater rates of leaching of the more mobile potassium and calcium cations (Dorn and Krinsley, 1991). Flakes of rock varnish were scraped off, mounted in epoxy, and measured by wavelength dispersive electron microprobe. The cation ratios fell into three groups:

a. Lower cation ratios felt to be "inherited" from the natural pavement; there were only one to three of these from each geoglyph; this low number is probably due to the initial field screening to well-varnished clasts and sample cobbles with pedogenic carbonate.

b. Higher cation ratios that are interpreted as cobbles exposed by gradual pavement reformation or human disturbance; these ratios were all higher than 9.0.
c. Medium cation ratios that are statistically indistinguishable from one another.

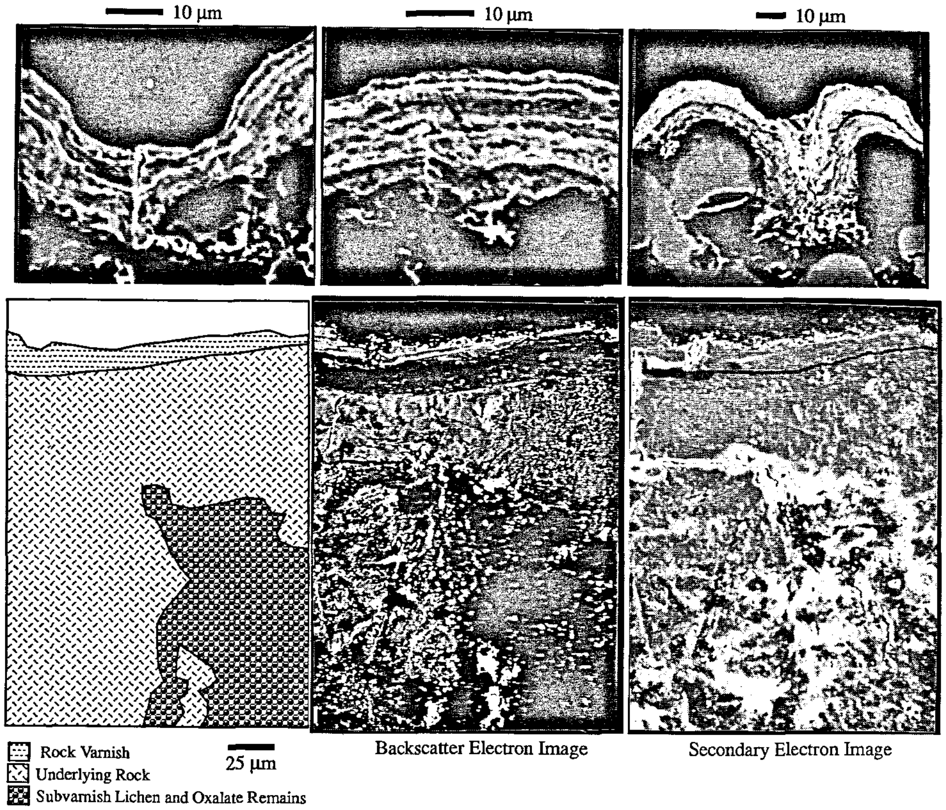
The cobbles with these intermediate cation ratios are interpreted to be those exposed by the process of geoglyph manufacturing, and were separated for further laboratory study.

There is controversy surrounding the cation-ratio method that was used to "preselect" cobbles for AMS sampling. These issues are reviewed elsewhere (Dorn, 1994a, 1994b; Francis et al., 1993), and many are beyond the scope of this research—because we are not using cation ratios to assign calibrated ages. We are only using the most basic assumption of cation-ratio dating, that cation ratios provide a *relative* age signal—a finding that has been replicated by several different groups of researchers (Bull, 1991; Dorn, 1983; Glazovskiy, 1985; Pineda et al., 1988; Taylor, 1994; Whitney and Harrington, 1993; Zhang et al., 1990). Even Bierman and Gillespie (1994), who have misrepresented data previously in this discussion (Cahill, 1992), present data that *the scraping technique* (which is used here) yields a valid relative age sequence comparing "cortex" and "flake scar" positions on artifacts in a desert pavement. "On both the mixed [scraped] samples, cultural [younger] varnish had higher CRs than adjacent noncultural [older] varnish (p. 87)."

We note, also, that cobble preselection relies on more than just varnish cation ratios. We purposely chose surface cobbles with calcrete skins, which indicates a former subsurface position. Since these sites did not display calcrete rubble on the surface, characteristic of an eroding landform, it is likely that the calcrete skins found on cobbles on the surface of the geoglyphs were exposed in the manufacturing of the earthen art.

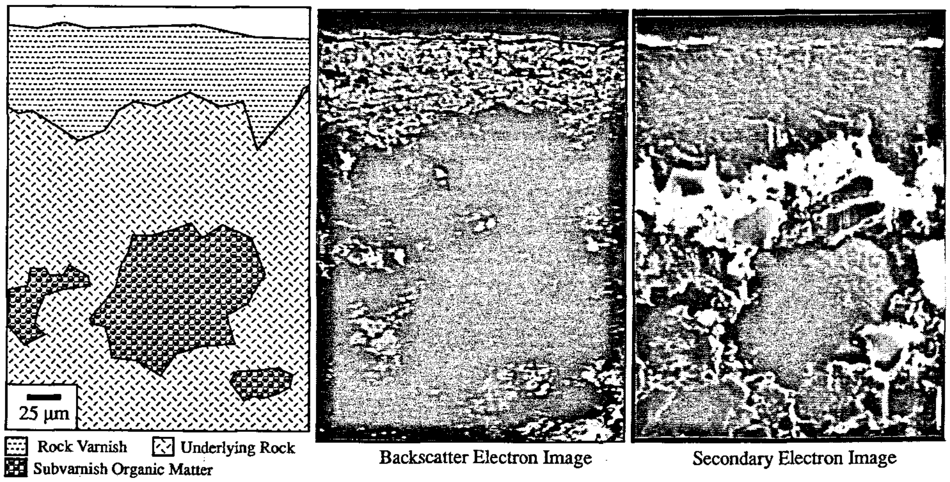
The second round of laboratory screening involved selecting only those microsites with layered rock varnishes (Figure 3). When rock coatings are not layered, there is a high likelihood that younger organics can contaminate a sample (Dorn, 1994a; Nobbs and Dorn, 1993). Tests that we employed to assess the interruption of layering are detailed elsewhere (Dorn, 1994a, 1994b; Krinsley et al., 1990).

After the removal (and testing) of layered varnishes, the upper 3 mm of the weathering rind underneath the varnish was then mechanically removed. The weathering rind material was then subject to the same pretreatment procedure of HCl, NaOH, HF, and hydroxylamine hydrochloride that removed potential contamination from younger organics in controlled tests (Dorn et al., 1989). Then, the organic carbon contents of the subvarnish rind, and weathering rinds in cobbles under adjacent desert pavements were determined by first processing the controls by the same pretreatment, and then determining the organic matter content by combustion methods (Dean, 1974).



Backscatter Electron Image

Secondary Electron Image



Backscatter Electron Image

Secondary Electron Image

That organic matter is found in weathering rinds should not be surprising. Others have found organics encapsulated in the outer rind of natural (Friedmann and Weed, 1987; Krumbein and Dyer, 1985; Weed and Ackert, 1986) and anthropogenic (Brown and Martin, 1993) rock material. "Finally, many archaeological materials, e.g., ceramic, plaster, daub, and bricks, frequently contain botanical remains, particularly small tissue fragments . . ." (Goldberg et al., 1994: 255).

RESULTS

Table I presents AMS ^{14}C measurements on organics extracted from underneath rock varnish. Also presented in Table I are concentrations of organic carbon in the "control" weathering rinds and the concentration of organic carbon in the dated material. The cation ratios of the dated samples are provided in Table I for comparison purposes, because these cation ratios assisted in the preselection of samples for ^{14}C measurement. We note that these cobbles also had calcrete fragments, indicative of a former position within the soil.

Four classes of potential errors are identified, the first being analytical measurement of ^{14}C, which is minimal and identified in Table I. A second error involves the possible addition of older organic carbon supplied from deposition of dust, for example, derived from deflation of adjacent soils (cf. Dorn et al., 1989). This error is discussed in greater detail in the next discussion section.

A third class of error involves the addition of organic carbon from the weathering rind that was "inherited" from a time before geoglyph exposure. To test this effect, unexposed cobbles from underneath the desert pavement adjacent to the geoglyph were collected. As indicated in the methods section, the upper 3 mm of these "control" weathering rinds were mechanically removed and subject to the same pretreatment procedure. The percent carbon remaining in a combustion was used to calculate potential contamination. It is likely that the rind organics would push the ^{14}C age in an older direction, but since the ^{14}C activity of this rind carbon was not measured, we do not know if it had a

Figure 3. Electron microscopy illustrating the microstratigraphy of rock coatings and encapsulated organic matter. The top row exemplifies backscatter electron micrographs (BSE) of the types of layered varnishes that we used and are appropriate for sample processing (left to right: Quartzite amorphous, Winterhaven stick figure, Ripley Complex lizard). In the middle (Quartzite Anthropomorph) and lower (Schneider Dance Circle) rows, BSE and secondary electrons are used to exemplify the spatial context of organic matter in the weathering rinds underneath rock varnish. Organic matter is dark in BSE but shows topographic expression with secondary electrons. The greater abundance of carbon in the mapped areas was also verified with wavelength dispersive electron microscopy. The speckled pattern of interspersed white dots in the area of organics in the middle row (Quartzite Anthropomorph) is typical of oxalate (Traquair, 1986) minerals that may "be the result of metabolic activity of lichen or fungi at the surface . . ." (Russ et al., 1994: 170).

Table I. Data for geoglyph samples.

Site	Geoglyph	(K + Ca]/Ti Ratios on Dated Cobbles	OC in Dated Sample (g/g)	AMS C-14 Age	Lab No.	OC[b] in Rind (g/g)	Total Error	Calibrated Age[c] (1 sigma)
1[a]	Winterhaven Stick Figure	8.30 ± 0.51	0.22	840 ± 25	OS-2158	0.025	228	A.D. 991 (1222) 1392
2	Pilot Knob Anthropomorph	8.24 ± 0.60	0.07	945 ± 25	OS-2159	0.043	377	A.D. 679 (1044, 1104, 1112, 1147, 1151) 1403
3	Blythe Giant Anthropomorph 1	8.24 ± 0.43	0.09	1060 ± 65	ETH-6572	0.009	137	A.D. 875 (997) 1158
3	Blythe Giant Quadruped	8.16 ± 0.31	0.19	1145 ± 65	ETH-6575	0.017	203	A.D. 668 (892) 1152
3	Blythe Giant Anthropomorph 2	7.90 ± 0.33	0.11	1195 ± 65	ETH-6574	0.011	154	A.D. 668 (878) 1011
4	Largest Anthropomorph, Ripley Complex	7.90 ± 0.75	0.13	1260 ± 60	OS-1331	0.015	185	A.D. 631 (776) 987
5	Largest Anthropomorph, Quartzite Airport	7.72 ± 0.34	0.09	1380 ± 25	OS-1831	0.014	142	A.D. 550 (660) 783
5	Amorphous Form, Quartzite Airport	7.80 ± 0.40	0.14	1480 ± 25	OS-1830	0.011	113	A.D. 443 (605) 663
5	Quartzite Anthropomorph, Second Analysis	7.72 ± 0.34	0.25	1540 ± 25	OS-2162	0.004	57	A.D. 440 (544) 604
4	Lizard (fertility) Figure, Ripley Complex	7.70 ± 0.39	0.07	1560 ± 40	OS-1268	0.043	392	A.D. 71 (538) 886
6	Singler Complex, Head Section	7.75 ± 0.47	0.12	1600 ± 25	OS-2161	0.027	242	A.D. 213 (439) 666
7	Museum Site Complex 'Snake', nr Ocotillo	7.14 ± 0.62	0.06	2640 ± 30	OS-2163	0.043	386	1264 (805) 267 B.C.
8	Schneider Dance Circle, Yuha Mesa	7.18 ± 0.54	0.08	2790 ± 25	OS-2160	0.028	249	1294 (916) 772 B.C.

[a] Site numbers correspond to Figure 1.
[b] OC refers to organic carbon extracted by the pretreatment procedure specified in the text.
[c] Calibration from Stuiver and Reimer (1993).

"modern" or "infinite" ^{14}C age. Additional error terms were calculated by assuming all of this rind carbon was either:

$$\text{modern: } 8033 * \ln[F_{\text{modern}} + (F_{\text{modern}} * C_{\text{contamination}})];$$
$$\text{or infinite: } 8033 * \ln[F_{\text{modern}} - (F_{\text{modern}} * C_{\text{contamination}})].$$

The "total error" in Table I combines AMS measurement uncertainty and this calculated uncertainty. The calibrated ages (Stuiver and Reimer, 1993) in Table I are based on this total error.

A fourth class of error, factors that would make the ^{14}C ages younger than the true age of geoglyph manufacture, is difficult to quantify. (1) There is an inherent time lag between the exposure of a geoglyph cobble and the onset of coating development. Studies of varnish on historical surfaces (tombstones, buildings) in the southeastern California region indicate that it takes about 80–110 years for varnish to start to form (Dorn, 1989). (2) Rock varnish grows vertically and horizontally from these colonization sites, making varnish growth a time transgressive process. (3) Aeolian abrasion has been active at the Schneider Dance Circle and Museum sites (Sites #7 and #8 in Table I). Aeolian abrasion would "reset" the varnish clock.

(4) Because of the small sample size involved, there is always the chance for contamination of organics within the varnish or boring underneath varnish. This potential is minimized by first removing the rock varnish entirely, and by examining cross-sections to avoid unlayered varnishes (Figure 3). If this contamination was present, however, it would have the effect of adding in younger ^{14}C material. This point is emphasized by the work of Watchman (1992) who extracted plant fibers from within unlayered rock varnish and reported their ^{14}C measurement. The age was predictably younger than organics extracted from under layered varnish from the same area (Nobbs and Dorn, 1993), because unlayered varnish is not a closed system (Dorn, 1994a). However, Watchman's ^{14}C age on intravarnish organics emphasizes two points: an intact stratigraphy (Figure 3) is essential; and intravarnish organics tend to make ^{14}C ages younger than subvarnish organics.

(5) Vadose water flowing through charcoal in soils and paleosols contains younger organic carbon that can sort onto mineral material such as clays (Burchill et al., 1981; Gillespie, 1991; Hedges and Hare, 1987; Heron et al., 1991; Osterberg et al., 1993; Warren and Zimmerman, 1994). Similarly, capillary water flows through rock varnish (Dorn and Krinsley, 1991), which could transport younger organics to be adsorbed on varnish and weathering rind clays.

This last class of younger error raises an apparent contradiction between the ^{14}C and cation-ratio methods of dating the onset of rock varnish. How can cation ratios be an open system of cation exchange and carbon be in a closed system? This is analogous using charcoal ^{14}C ages *and* soil profile development in the same system—a common practice in geoarchaeology. All during soil genesis, vadose water runs through the soil and the charcoal; yet both soils and charcoal are regularly used together, as open and closed systems, respectively. In fact, ^{14}C ages are often used to "calibrate" soil development, yet this issue is rarely raised.

The solution used in both soils and varnish rests in the pretreatment of both varnish organics and sediment charcoal; the object of the pretreatment is to remove younger organics that do flush through a sample with capillary water. In the case of varnish-sealed organics, treatment with HF was designed to remove the clay-adsorbed organic molecules (Dorn et al., 1989), but there is always the possibility of incomplete removal of younger organic molecules. Gillespie (1991) also found that harsh acid–base pretreatment was necessary to bring ages, in this case on soil charcoal, in line with independent control. Without harsh pretreatment, ages for both varnish (Dorn et al., 1989) and soil charcoal (Gillespie, 1991) were younger than independent controls.

Given these inherent uncertainties, we interpret the calibrated age ranges in Table I from the perspective that they represent minimum limits for the geoglyphs. In other words, the organic carbon that was measured was most likely encapsulated by varnish sometime after the geoglyph was made. However, these minimum ages, along with other AMS ^{14}C measurements on rock art in a surficial context, should be treated as experimental for reasons outlined in the next section.

DISCUSSION

Cloud of Uncertainty: Contemporeneity of Carbon on Rock Surfaces

Our interpretations assume that the carbon encapsulated by rock varnish is penecontemporaneous with the sealing event. However, there is the theoretical possibility that this may not be true. One possibility is that older organic carbon, deflated from adjacent soils, might be trapped by rock varnish (Dorn et al., 1989). Others have speculated that older organics might be deflated from playas (Reneau et al., 1991).

Available empirical data reveals that organic matter that is encapsulated by rock varnish is younger than independent controls (Dorn, 1994a; Whitley and Dorn, 1993). Unfortunately, there is little data to assess objectively if there is a bias for organics on today's rock surfaces. ^{14}C ages of 10^3 years were measured on active cryptoendolithic microorganisms in Antarctica (Bonani et al., 1988). Remains of an unvarnished dead lichen in a weathering rind on the sampled Quadraped geoglyph from Site #3 (Table I) yielded a ^{14}C measurement of 205 ± 55 B.P. (AA-6902). Filaments in a weathering rind under live epilithic lichens growing in a *Drominorthid* track petroglyph in South Australia yielded a ^{14}C measurement of 687 ± 84 B.P. (NZA 2275), whereas organics encapsulated by rock varnish were 14,910 ± 180 B.P. (NZA 1367; see Nobbs and Dorn, 1993:27) for the same petroglyph.

This discussion dances around a larger issue that has been virtually ignored in the AMS ^{14}C measurement of surficial organic materials in rock art (Watchman, 1993b). Small samples are easily "contaminated" by noncontemporaneous organics. While Chaffee et al. (1994) account for organics in weathering rinds, as we do, this topic is larger than just the influence of older carbon in weathering rinds. The bias could potentially be systematic at a particular site, thus affecting an entire "stratigraphic column" of surficial materials (Watchman, 1993a), or it may be more chaotic—and depend upon the individual history of detrital fragments.

Our concern here is threefold. First, the geography of the contemporenity of organics in different surficial settings should be a high research priority for all who wish to interpret the ^{14}C ages of organics in a surficial context. Second, pretreatment of organics found in a surface context either does not always occur (Watchman and Lessard, 1992) or at least is not discussed (Watchman, 1993a), yet an important part of the history of radiocarbon dating is the pretreatment of samples (Taylor, 1987). This is especially true for samples exposed to meteoric and vadose water. Third, the type of organic matter has been similarly important in radiocarbon dating (Taylor, 1987), but is often uncertain.

In all fairness, these are difficult issues. Sometimes, insufficient sample exists to "risk" loss of some component in pretreatment, or laser extraction procedures are incompatible with current approaches at sample pretreatment (Nobbs and Dorn, 1993). In other cases, it is not possible to definitively identify the nature of the organics. For example, although we suspect that we were dating lichen or fungal remains (Figure 3), we will never to sure due to sample diagenesis. Until these uncertainties are addressed, however, we believe that all ^{14}C ages on surficial rock art must be viewed as experimental.

Speculative Thoughts on the Earliest Geoglyphs and Yuman Migration

One hypothesis regarding the geoglyphs is that they were made by Yumans as they expanded into the desert. A people's embracement of a new country (von Franz, 1970), even after such a slow-paced *Völkerwanderung,* has seldom been more complete. The creation myths of the Yumans center on their adopted desert lands (Alvarez de Williams, 1974; Cline, 1979; Forde, 1931; Johnson, 1986; Kroeber, 1925; Luomala, 1978).

Ethnographic and archaeologic evidence indicates that geoglyphs played an active role in certain Yuman rites (Gifford, 1931; Johnson, 1986). According to Yuman (Kumeyaay, Mojave, and Quechan) informants, the making of geoglyphs was conducted on sacred grounds and included the depiction and celebration of the creation myth, the keruk (annual mourning) ceremony, initiation rites for boys and girls, and cultural renewal with traditional dancing and singing. The figures formed on the ground emphasize the importance of mother earth as the source of fertility and power, as seen in the care and use of certain rock (von Werlhof, 1986, 1989).

Studies in glottochronology and lexicostatistics hypothesize that about 4000

B.C. the Yuman–Cochimi occupied a sector of north-central Baja California (Kendall, 1983; Laylander, 1985). By about 3000 B.C. the Yumans had advanced northward to near the present México–United States border, and about 1000 B.C. had spread across what is now San Diego and Imperial counties in southern California. By A.D.0, this model has the Yumans moving up river along the lower Colorado and Gila rivers. Since geoglyphs are an important and recognized part of Yuman culture, the minimum ^{14}C ages for the geoglyphs could potentially place a constraint on the timing of Yuman migration into the region.

The coastal and Peninsular Yuman bands did not practice earthen art, but those that turned eastward into the desert did. The minimum ages of 1264–267 B.C. for the Snake at base if the Peninsular Range in Ocotillo, Imperial County and of 1294–772 B.C. for the 85 m dance circle on Yuha Mesa 10 miles further east are the oldest measurements. These earliest minimum ages, therefore, would be consistent with this Yuman migration model.

Later Geoglyphs

The other minimum ages in Table I are all later than A.D. 0 and would be consistent with Yuman occupation of the entire region by that time. The next three oldest ^{14}C measurements center around A.D. 440–550 (Sites #4, 5, and 6 in Table I). Before A.D. 71–886, a "lizard" element (a possible fertility figure) was made at the "Ripley Site" in Arizona, across the Colorado River from Ripley, California. An anthropomorphic figure at Quartzite, Arizona, has two AMS measurements. Since both are minimum ages, the best interpretation is that the figure was made before A.D. 440–604, indicating that the geoglyph tradition had spread into the southwestern Arizona region by this time. It is possible that other samples from these geoglyphs or other geoglyphs could yield minimum ages that could more closely constrain the timing of Yuman occupation—with the premise that geoglyphs are characteristic of Yuman culture (Forde, 1931; Gifford, 1931; Johnson, 1986).

In the southeastern corner of Imperical County, two sampled geoglyphs (Sites #1 and #2 in Table I) are anthropomorphs that the Quechan identify as Kumastamo, the creator. These are the youngest ages we obtained. Their minimum age ranges overlap at A.D. 991–1392 and A.D. 679–1403. Significant in situ "use" of the geoglyphs must have ceased by this time, or the disturbance would have reset the clock.

Minimum ages for the remainder of the geoglyphs, including the "Blythe Giants" (Site #5, Table I), overlap in the time range of A.D. 550–1150. Although data are limited, our minimum ages would be consistent with the hypothesis that sites were made over long periods of time and that elements were gradually added. Perhaps the process of geoglyph making was as important as, and maybe more important than, the product. It may be that growth, continuity, and longevity are essential parts of the geoglyph tradition and vital to the preservation of the culture.

Our ^{14}C age constraints, however, conflict with cultural and historic construction of tribal origins and deployment sometimes cited in ethnographic and archaeological sources, where the homeland of Yumans is placed in the north and where they migrated southward through the Colorado Valley and westward to the coast (Fowler, 1983; Sutton, 1992). In this model, arrival into the lower Colorado River country is usually placed about 1000 years ago. Since our geoglyph ages are best interpreted as minimums for the time of manufacturing, the people who manufactured the geoglyphs (presumably Yuman) must have arrived well before A.D. 1000. As noted earlier, our ages are consistent with earlier linguistic studies (Kendall, 1983; Laylander, 1985) indicating a Yuman migration from Baja California in the south.

CONCLUSION

This article advances the study of geoglyph chronology in several ways. Empirically, we add 10 new AMS ^{14}C measurements to the database of geoglyph chronology. Methodologically, we include weathering rind organics as a potential contaminant. Although we did not have the funds to measure directly the ^{14}C age of the rinds, we add its effect to the measurement error. Theoretically, instead of supporting an earlier interpretation of chronological simplicity (Dorn et al., 1992), our data indicate that geoglyphs were made over an extended period: from before ~A.D. 1200 to before ~900 B.C. Although our dataset is small, it is consistent with the linguistic hypothesis that the Yuman people migrated from the south and came over the Peninsular Range from coastal California—rather than from the north.

Considerably more work is necessary to understand the chronology of earthen art, even within the relatively small area around the Colorado River of Southwestern North America (Figure 1).

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