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Review Article

Rock Art Dating and the Peopling of the Americas

David S. Whitley

ASM Affiliates, Inc., 24160 Woodbine Court, Tehachapi, CA 93561, USA

Correspondence should be addressed to David S. Whitley; huitli53@gmail.com

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The peopling of the Americas is both the oldest and most frequently researched question in American archaeology. Although rarely considered, early art has the potential to provide insight into questions that may be obscured by other kinds of evidence, particularly stone tools. What part did art play in the peopling of the Americas? This question is addressed starting with a reconsideration of rock varnish chronometrics as applied to Great Basin, eastern California, petroglyphs. This demonstrates, conservatively, that the petroglyph tradition began before 11,100 YBP, probably before 12,600 YBP, and potentially in the 14,000 years range. Comparison of these ages with evidence from other regions in the hemisphere demonstrates substantial artistic and stylistic variation in rock art by the Paleoindian period (circa 10,000–11,000 YBP). This suggests that, while art may have been part of the baggage of the first immigrants, regional cultural traditions had already been developed by the Terminal Pleistocene, if not earlier. The result is evidence for the development of regional cultural diversity in the Americas by Paleoindian times.

1. Introduction

Few New World archaeological problems have received more attention than (and experienced as much debate as) the initial peopling of the Americas. Even with decades of research, basic questions like the earliest entry date and colonizing route remain elusive. Despite these uncertainties, the majority opinion currently seems to maintain that humans first arrived sometime prior to 13,000 years ago, though how much earlier is unknown (e.g., [1, 2]). More confidently, there is a consensus that the initial immigrants where *behaviorally modern*, in the archaeological sense of these terms (e.g., [3]). A key attribute of archaeological modernity is the ability to conceptualize and employ symbols, including the capacity to make and use art [4]. Although we still do not know when humans arrived in the Americas, we can assume that they were fully capable of producing art, and potentially had the proclivity to do so. But what and where is the evidence for the earliest American art, and what does it tell us about the peopling of the hemisphere?

Recent research in North and South America, including improvements in chronometric techniques, has amplified our understanding of Terminal Pleistocene/early Holocene art. This demonstrates that it is more common than generally recognized, includes both portable and landscape (i.e., rock) art, and exhibits considerable geographical and stylistic variability. These studies are summarized below with the intent of providing a hemisphere-wide overview of early symbolic behavior. My point of departure in this discussion is a chronometric reanalysis of Great Basin petroglyphs (rock engravings), directed specifically at identifying the earliest art in far western North America. This necessarily requires a discussion of recent advances in petroglyph dating techniques before turning to the larger issues at hand.

2. Great Basin Rock Art

Great Basin petroglyphs are well known due to influential early syntheses of this art [11, 12]. Particularly notable are the petroglyphs of California's Mojave Desert, including a massive concentration in the Coso Range [13–21]. No accurate figure has been obtained for the number of Coso motifs, but credible estimates vary from hundreds of thousands to millions of individual engravings. It is believed to be the largest rock art concentration in the Americas, and perhaps one of the biggest in the world. The Coso corpus is also notable because of its emphasis on iconic or representational imagery

(Figure 1), especially the bighorn sheep (*Ovis canadensis*), which constitutes roughly half of all of the engravings, based on Grant's [13] tabulation. Stylized anthropomorphic figures of various types are also common, with a smaller number of canids/felines, snakes, weapons, and a few other identifiable designs. But simple and complex geometric designs are typical (roughly one-third of the total) and are frequently intermingled with the ostensibly identifiable images.

At other Great Basin sites, outside the Cosos, the same motif assemblage typically occurs, although geometric designs commonly predominate. The Coso petroglyphs vary from the remainder of the Great Basin art not due to significant stylistic or known cultural differences but instead as a function of variations in the proportional motif emphases at individual sites and within smaller regions. One result is the fact that this widespread corpus is sometimes labeled the "Great Basin Archaic Style" (e.g., [23]) although, as we shall see, it was neither solely nor predominantly produced during the Great Basin Archaic period (circa 5000–1000 YBP).

Figure 1: Mojave Desert, California, rock engravings are predominated by images of bighorn sheep, followed numerically by anthropomorphic figures and next by a variety of geometric forms. This example is from Sheep Canyon in the Coso Range. (Photo by Whitley.)

3. Petroglyph Chronometrics

Any discussion of potential early art requires a consideration of dating; in this case, rock art chronometrics and much of the early rock art chronometrics research was conducted in the Coso Range and Mojave Desert (e.g., [24–28]). By the mid-1990s, three independent rock varnish dating techniques had been developed and applied to petroglyphs: cation-ratio (CR) dating, varnish microlamination (VML) dating, and AMS ^{14}C dating of weathering rind organics (AMS-WRO; e.g., see Dorn [29–31]). An unfortunate controversy developed concerning this last technique in the late 1990s[1]; one result of which is the widespread but incorrect assumption among archaeologists that rock varnish dating as a whole is no longer viable [32]. Although AMS-WRO dating is in fact currently unusable [33, 34], the controversy strictly had no implications for the other techniques, and significant geomorphological research on them has occurred in the interim. CR and VML dating, accordingly, have been used to reassess the Great Basin petroglyph chronology. In light of the varnish dating controversy and the uncertainties and misunderstandings that it generated, I discuss the current status of these two chronometric techniques before turning to the revised rock art chronology.

3.1. Cation-Ratio Dating. The CR technique was developed by Dorn and first applied to petroglyphs in the early 1980s [24–27, 29–31, 35–38]. Though initially employed in the Americas, it was subsequently used in South America, Africa, Asia, and Australia (discussed below). It is based on cation exchange processes in the rock varnish that coats many petroglyphs in arid regions. These processes leach out mobile trace elements (notably potassium and calcium), through capillary action, more rapidly than less mobile trace elements (particularly titanium; see [29, 30, 39–42]). The rate of change can be calibrated regionally, using independently dated control surfaces, such as varnish-covered basalt flows. An electron microprobe is typically used to measure the chemical constituents of varnish samples, which are pin-head sized flakes that are removed from the engraved-out portion of a revarnished petroglyph.

The first CR petroglyph dating results were controversial in two ways. On the archaeological side, the initial research focused on presumed earliest motifs and (unexpectedly) obtained a handful of pre-Clovis aged results [26, 27, 43, 44], that is, dates older than 11,200 years old, then assumed to be the start of the Clovis period. When these dates were first reported, many North American archaeologists considered them an empirical impossibility, due to the then-prevailing consensus concerning the Clovis first peopling of the Americas[2]. The result was extreme skepticism, if not outright rejection, of the newly introduced technique, for straightforward reasons: the chronometric ages were older than the presumed first peopling of the Americas. Two decades later, archaeological opinion has reversed and now supports greater time depth for the initial colonization of the hemisphere. This change in circumstance does not prove that the pre-Clovis CR ages were correct, but it negates the original archaeological argument against and attitude towards the technique.

Some initial debate also occurred on the geochemical/geomorphological side. As is often the case with research on new topics, this resulted partly from simple confusions; first over techniques and analytical measurements used to assay the varnish sample chemistry (e.g., [29, 30, 45, 47]); and second involving differences in the kinds of rock varnish studied (e.g., [29, 30, 48, 49]). But skepticism also occurred because of one scientist's failure to replicate the technique, and widespread promotion of that fact [29, 50–52].

Replication is often considered the gold standard of science, yet there are multiple potential reasons why a replicative test might fail, beyond the validity of a technique alone (e.g., differences in field sampling, or sample preparation approaches; see [53]). Regardless of the cause for Watchman's [29, 50–52] repeatedly published failure, the more relevant point is that many research groups have replicated CR dating, worldwide, both before and after his failed Australian effort (e.g., [54–64]). Included in these is my own replication, fully independent of Dorn and his lab, in southern Africa [65]. In addition to multiple replications, the technique has also been successfully subjected to petroglyph dating blind tests [66–69].

Though I discuss the validity of CR dating in more detail below, it is worth noting here simply that it has analytical weaknesses, probably the most pronounced of which is that it is based on geochemical processes and these potentially can reverse over time. Although the initial CR dates were experimental, their recent combination with VML dating (below) provides greater scientific confidence in the resulting assigned petroglyph ages.

3.2. Varnish Microlamination Dating. Perry and Adams [70] first observed continuous orange microlayers in thin sections of rock varnish, interbedded with black bands, representing manganese-poor and manganese-rich layers, respectively. Subsequent research has shown that these microlaminations occur over wide regions and correlate with major paleoenvironmental changes—alternating dry and wet periods [29–31, 37, 71–76]. Through the use of independently dated control surfaces, Dorn developed a relative/correlative technique, VML dating, based on the analysis of this layering, first as seen in micrographs and subsequently in thin sections. It is conceptually analogous to dendrochronology in that it involves the identification of regional microstratigraphic signatures (similar to tree growth patterns) caused by climate change, although it lacks the temporal resolution of tree-ring dating.

The initial utility of VML dating in fact was hampered because it was restricted to a layering sequence for the Late-Terminal Pleistocene. Micrographs showed the Pleistocene-Holocene boundary as a change in micromorphology, with botryoidal layers developing during the earlier wetter period and lamellate varnish during the drier Holocene. The shift from botryoidal to lamellate micromorphology is currently understood as the change from the LU1 to LU2 paleoclimatic periods (terminology from [6–8]; see Figure 2) and is set at about 12,500 yrs cal BP.

The microstratigraphic distinction proved to be more easily seen in thin section, and Dorn identified seven Pleistocene wet event dark layers that are rich in Mn and Ba, matched by six intervening less wet period light layers that are rich in Si and Al. The sequence initially extended from 12,500 to about 60,000 cal yrs BP. The only visible microstratigraphic change (whether seen with micrographs or thin sections)

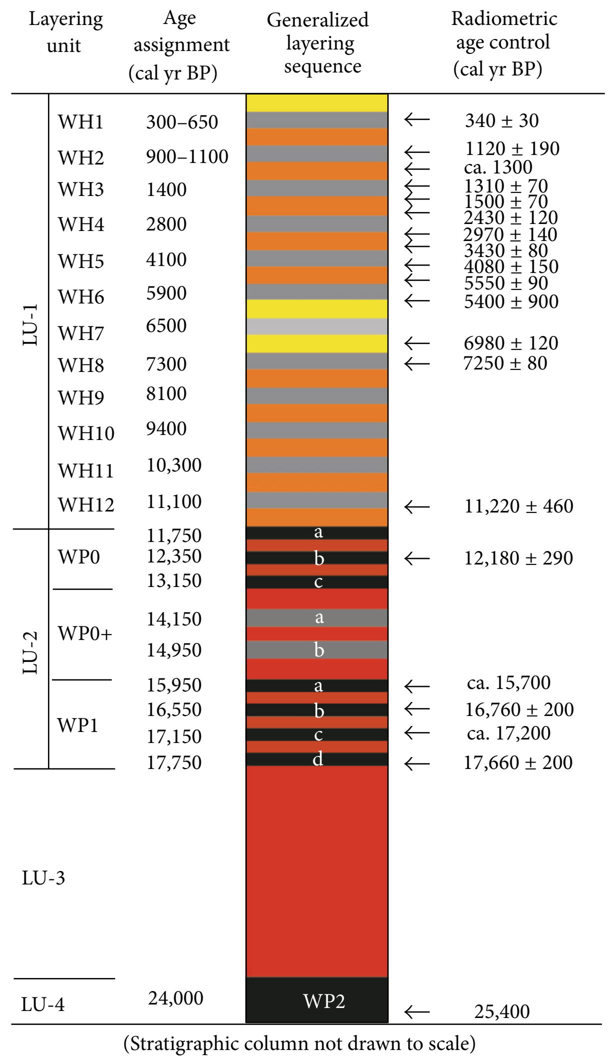


Figure 2: Holocene and Late Pleistocene VML calibration, as defined by Liu [5–10]. (Image courtesy of Liu.)

in the archaeological time range then was the Pleistocene-Holocene boundary, thereby effectively precluding the use of the technique for most of the New World archaeological record.

Although originally developed by Dorn, Tanzhuo Liu improved and extended the technique subsequently, working at the Lamont-Doherty labs at Columbia University with Wallace Broecker. Liu's research included over a decade of analyses involving more than 10,000 varnish samples. It resulted in improved temporal resolution of the Pleistocene sequence and the extension of the technique back to about 140,000 cal yrs BP [75]. It also included a blind test matching VML results against cosmogenic dating [77, 78]. The journal editor who oversaw this test concluded that "[r]esults of the blind test provide convincing evidence that varnish microstratigraphy is a valid dating tool to estimate surface exposure ages" ([79], p. 197).

Liu more recently has defined the Holocene VML sequence for the Mojave Desert [5–10], making the technique fully applicable for archaeological purposes in this region. Liu's Holocene sequence includes twelve wet event dark layers and thirteen dry event lighter layers that bracket the period from 300 cal yrs BP to 12,500 yrs cal BP. The lengths of the intervals between wet events vary from 250 to 1800 years, with an average of 970—roughly 1000 years. The resulting correlated VML ages are certainly not as precise as radiocarbon ages, but they are adequate for age assignment to the broad time periods comprising the regional cultural historical sequence.

Importantly, VML dating has been independently replicated and applied to the archaeological record by different research teams working in the Sahara Desert [80–83], and Argentina [84]. Although regional microlamination sequences appear to vary and require local calibration, the Saharan, South American, and other international studies [85, 86] indicate that VML has the potential for widespread application in arid and semiarid environments.

4. Reevaluating the Great Basin Petroglyph Chronology

As noted above, a blind test of VML and cosmogenic dating [77, 78] provided "convincing evidence" of the validity of the VML technique ([79], p. 197). Over a decade of research also resulted in a Holocene VML calibration ([5, 7–10]), making this approach widely applicable in archaeology. This calibration was developed for the Mojave Desert, thereby facilitating its application to the Coso Range and other eastern California petroglyph localities, and accommodating its use as an independent check on CR dating.

In order to reevaluate the Great Basin petroglyph chronology, a series of chronometric analyses were conducted, some of which involved blind tests, with the assistance of Dorn and Liu, each working independently. These involved dating newly sampled petroglyphs and archived petroglyph varnish samples and thin sections, combined with previously obtained petroglyph ages from six rock art localities in the Mojave Desert: the Coso Range, CA; Fort Irwin, CA; Rodman Mountains, CA; Cima volcanic field, CA; Sacaton Wash near Lake Mead, NV. Sixty-seven petroglyphs and one natural control rock surface are included in the sample, representing 106 independent chronometric assays[3] (Table 1)—one of the largest chronometric rock art data sets in the world. These data were obtained and analyzed in the following fashion.

(1) Previously published petroglyph CR ages are from Dorn [37], Whitley et al. [20, 21], Whitley [18, 87], and Whitley and Dorn [28]. Note that these have all been calculated without the use of AMS-WRO ages in their calibrations.

(2) Dorn had previously prepared 25 varnish thin-sections from CR dated petroglyphs. Prior to Liu's Holo-cene VML calibration, these could not be interpreted, beyond the potential presence of the Pleistocene/Holocene marker. Using the published Holocene calibration [5–10], Dorn chronologically interpreted and annotated images of each of these thin sections. Liu then evaluated Dorn's interpretations, in order to confirm, reject, or qualify the temporal placements.

(3) Dorn also had archived six varnish samples from CR dated surfaces (five petroglyphs and one natural control surface), that is, specimens that had not yet been made into thin sections. These were submitted to Liu blindly: he received no information on the identification or previously determined age of these samples. Liu prepared the thin sections and interpreted the results. Liu's results were subsequently evaluated by Dorn, for confirmation, rejection, or qualification.

(4) Liu was taken to the Coso Range in order to collect new VML samples. This too was conducted as a blind test in the sense that the primary goal was to resample previously dated petroglyphs to confirm or reject their pre-existing calculated ages, as well as to sample additional engravings. Liu was given no information on the name of the sites visited, the previous petroglyph ages, or their sample identifications in the literature. In order to include as many cross-checks as possible, Liu's VML interpretations were also independently evaluated by Dorn. Both analysts cross-checked each other's results, reflecting the facts that VML dating requires a visual interpretation of the thin sections, and the goal was to obtain the most certain results possible.

Two points need emphasis in order to understand the results. The first concerns Liu's convention in reporting VML ages. VML analyses involve the identification of the time period during which revarnishing began to develop. As noted above, during the Holocene these periods average about 1000 years in length, but their spans range from 250 to 1800 years. Liu reports his VML ages as single dates (e.g., 5900 or 2800 cal yrs BP) associated with specific microstratigraphic layers (WH6 and WH4, resp.), however, rather than as temporal spans. His use of this convention is intended to emphasize the fact that these are minimum-limiting ages, not specific calendrical determinations.

There are two implications of this circumstance. VML ages should be understood as minimum temporal approximations, not as "absolute" ages. This reporting convention, however, makes cumbersome the comparison of VML results to other chronometric ages in standard form (using a comparison between calculated standard errors). Nonetheless, the VML ages are adequate for the construction of a petroglyph chronology, and for a generalized independent evaluation of CR dating.

It is also important to highlight the nature of the cross-evaluations by Liu and Dorn of each other's prepared and interpreted VML thin sections. The objective was to obtain confident temporal assignments. For a variety of reasons, Liu and Dorn did not in all cases concur, thereby qualifying the other analyst's interpretation. Note however that none of the VML readings were rejected as clearly in error by either analyst; instead in some cases Liu or Dorn felt that additional sampling and thin sections are required for full confidence in specific inferred minimum-limiting ages. Although I use

Table 1: CR and VML dated petroglyphs from the western Great Basin.

Sample no.	Description	CR age (yrs cal BP)	Dorn VML/(comment) (yrs cal BP/VML layer)	Liu VML/(comment) (yrs cal BP/VML layer)
CM-12	Bighorn	16,500 ± 1000	17,750/Wp1d	(Needs additional sampling)
			(Botryoidal under Lamellate/>12,500)	—
= Coso 3			(Needs additional sampling)	5,900/WH6
= Coso 4			(Confirmed)	5,900/WH6
CM-5	Curvilinear	15,100 ± 1600	12,500–16,500/WPO+	(Needs additional sampling)
LL-1	Spiral	14,500 ± 1,300	>16,500/LU-3	(Needs additional sampling)
			(Pleistocene Owens River age: <16,200 [22])	
R96ST13	"Llama"	13,400 ± 2000	17,150/WP1c	(Needs additional sampling)
			(Overlying oxalate AMS 14-C age: 11,860 ± 60, Beta 90197)	
BSS3	Curvilinear	13,100 ± 1600	(Botryoidal under lamellate/>12,500)	—
CM8	Curvilinear	12,600 ± 1400	None	—
CM15	"X-motif"	12,000 ± 600	11,100/WH12	(Confirmed)
R-96-ST-2	Curvilinear	11,900 ± 1500	12,500/WPO	(Needs additional sampling)
Cima 2-5	Snake	11,700 ± 1000	(Entirely lamellate/<12,500)	—
CM-7	Bighorn	11,200 ± 1200	None	—
Coso 9	Geometric line	None	(Confirmed)	11,100/WH12
= Coso 10			(Confirmed)	11,100/WH12
R-96-ST-3	Curvilinear	9700 ± 1200	10,300/WH11	(Confirmed)
Coso 14	Curvilinear	None	(Confirmed)	9400/WH10
= Coso 15			(Confirmed)	9400/WH10
R-96-ST-5	"Grid"	9400 ± 1600	14,150/WPO + a	(Needs additional sampling)
			(Overlying AMS ^{14}C oxalate age: 9830 ± 60, beta 89921)	
BSS2	Curvilinear	8600 ± 4300	None	—
R-96-ST-8	Circle	8600 ± 1200	9400/WH10	(Confirmed)
Cima 1-2A	Curvilinear	8400 ± 1800	(Confirmed)	6500/WH7
Cima 1-3	Control surface	12,000	(Needs additional sampling)	8100/WH9
			(Single CR measurement)	
CM-6	Bighorn	7800 ± 600	10,300/WH11	(Needs additional sampling)
CM-2	Bighorn	7400 ± 700	None	—
LAME 94-1	Maze rectangle	6900 ± 140	None	—
CM-3	Bighorn	6800 ± 700	12,350/WPob	(Needs additional sampling)
WP4	"Shield"	6800 ± 4200	13,150/WPOc	(Needs additional sampling)
Cima 94-1	"Shield"	6400 ± 900	None	—
BSS1	Line	6400 ± 1200	None	—
WP2	Bighorn	6200 ± 1400	None	—
			(Chalk contamination—CR in error)	
CM4	Lizard	6100 ± 600	6500/WH7	(Confirmed)
Coso 5	Bighorn	None	(Needs additional sampling)	5900/WH6
= Coso 6	Bighorn	None	(Confirmed)	5900/WH6
= Coso 7	Bighorn	None	(Confirmed)	5900/WH6
Cima 1-3	"Pine tree"	5300 ± 200	(Confirmed)	5900/WH6
WP3	Grid	5100 ± 2400	None	—
CM16	Rectilinear	5100 ± 500	None	—
FI-96-22	Circle and line	4800 ± 600	None	—
LAME 94-5	Curvilinear	4600 ± 900	None	—
FI-96-16	Parallel lines	4500 ± 850	4100/WH5	(Needs additional sampling)
Cima 2-1	Curvilinear	4400 ± 200	None	—
CM-1	Bighorn	4300 ± 2100	None	—
Cima 1-2B	Random pecking	None	(Needs additional sampling)	4100/WH5

Table 1: Continued.

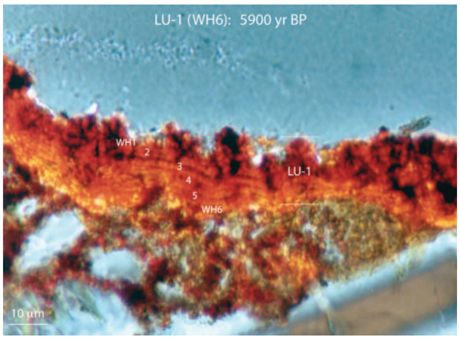
Sample no.	Description	CR age (yrs cal BP)	Dorn VML/(comment) (yrs cal BP/VML layer)	Liu VML/(comment) (yrs cal BP/VML layer)
CM10	Lizard	3600 ± 300	None	—
FI-96-19	Stick figure human	3300 ± 500	(Confirmed)	2800/WH4
CM9	Lizard	3100 ± 400	None	—
Cima 1-6	Dot pattern	3100 ± 200	None	—
FI-96-20	Circle and cross	3000 ± 500	2800/WH4	(Needs additional sampling)
LAME 94-2	Bighorn	2900 ± 400	None	—
FI-96-2	"Shield"	2750 ± 550	None	—
Cima 1-1	Curvilinear	2600 ± 200	None	—
FI-96-1	Bighorn	2500 ± 500	2800/WH4	(Confirmed)
LAME 94-3	Curvilinear	2400 ± 300	None	—
WP-1	"Sunburst"	2400 ± 200	None	—
Cima 2-2	Meander	2300 ± 200	None	—
Cima 2-3	Curvilinear	2100 ± 100	None	—
CM13	Bighorn	1900 ± 200	None	—
FI-96-10	Grid	1750 ± 250	None	—
CM11	Anthropomorphic	1500 ± 100	None	—
R-96-ST-6	Repecking on grid	1500 ± 600	(Confirmed)	1400/WH3
CM14	"Circle chain"	1300 ± 100	1400/WH3	(Confirmed)
R-96-ST-9	Atlatl	1200 ± 500	None	—
FI-96-4	Grid	1200 ± 200	None	—
FI-96-13	"Loop"	1150 ± 250	None	—
Cima 1-7	Rectilinear	1110 ± 200	1000/WH2	(Needs additional sampling)
FI-96-6	Oval	900 ± 250	None	—
Cima 1-8	Curvilinear	700 ± 100	650–900/WH1-WH2	(Confirmed)
Cima 2-4	"Rake"	400 ± 100	500/WH1	(Confirmed)
Cima 1-4	Dot and line	350 ± 200	<300/<WH1	(Confirmed)
FI-96-9	Bighorn	350 ± 100	500/WH1	(Needs additional sampling)
FI-96-8	Bighorn	300 ± 100	<300/<WH1	(Confirmed)
FI-96-14	Circle and cross	300 ± 100	<500/<WH1	(Confirmed)
Cima 1-5	Grid	300 ± 100	None	—
FI-96-12	Bighorn	250 ± 100	<300/<WH1	(Confirmed)

Key to sampling locale codes: Coso Range: CM, LL, WP, BSS, and Coso; Fort Irwin: FI; Cima volcanic field: Cima; Rodman Mountains: R; Sacaton Wash: LAME.

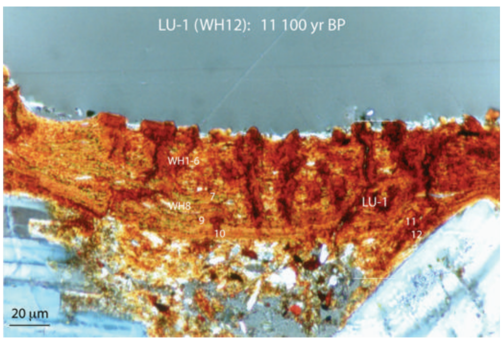
these provisional VML ages below, they should be recognized as not yet independently verified by a second analyst.

4.1. Analytical Concordance. The comparability of the results using the two dating techniques has implications at two levels: (1) the validity of CR dating in general terms, important in light of early controversies about this technique; (2) the evaluation of specific individual petroglyph ages. With respect to the accuracy of CR dating, 32 petroglyphs have both CR and VML ages (Figure 3). As noted above, the comparison of the results from these two techniques involves different mathematical conventions so that the standard criterion—whether the sets of ages overlap at one or two standard deviations—cannot be employed. That said, it is still apparent that the concordance between the two dating techniques is good, especially when both analysts agreed on the VML age assignments. Of the 32 CR and VML dated petroglyphs, half provide essentially complete concordance. Fourteen of the 32 have CR ages that statistically overlap the minimum-limiting VML ages confirmed by both analysts at one standard deviation. Another (barely) misses that standard by 100 years but matches it at two standard deviations. A third is slightly further off, Cima 1–3, a geometric ("pine tree" like) motif, has a VML minimum-limiting age of 5900 yrs cal BP, as determined by Liu and confirmed by Dorn. The CR age on this motif is 5300 ± 200 yrs cal BP. Although these two ages strictly are not statistically equivalent, they are both Early Archaic temporal assignments, falling within the same millennium. Another nine of the 32 engravings have CR ages that are confirmed by one VML analysis. The result is that 25, or 78% of the total of these CR ages, are independently supported by one or more VML analysis.

The immediate implication of these results is the following. CR dating is a usable even if imperfect chronometric technique. It clearly can provide a general sense of petroglyph temporal placement for a suite of samples, even though its



(a)



(b)

FIGURE 3: VML rock engraving thin sections. Layering unit LU-1 corresponds to the Holocene and LU-2 to the Late Pleistocene. Dark bands of the subunits represent wet phases as follows: WH1, Little Ice Age wet phase; WH2, Medieval Warm wet phases; WH3–WH6, Late Holocene wet phases; WH7, Mid Holocene wet phase; WH8–WH12, Early Holocene wet phases; WPO, Younger Dryas wet phase. (a) Coso-7, with confirmed VML minimum-limiting age of 5,900 yrs cal BP. (b) Coso-9, with confirmed VML minimum-limiting age of 11,100 yrs cal BP. (Images courtesy of Liu.)

accuracy on any specific single motif may potentially be in error. It is in this sense analogous to another geochemically based technique, obsidian hydration dating, which likewise is valuable for broad-spectrum chronological analysis but is influenced by too many uncontrollable variables to confidently "date" single artifacts (cf. [88]).

The comparison of the CR and VML ages also assists in the identification of incorrect chronometric ages—where the disparity between the two results is so great that one of the assays is clearly wrong. Four of the 32 CR and VML dated petroglyphs fall in this category. Two additional petroglyphs have ambiguous results, for various reasons. These too can be eliminated from any further consideration of the petroglyph chronology in the western Great Basin.

4.2. Revised Petroglyph Chronology. Three kinds of chronometric evidence are available for revising the western Great Basin petroglyph chronology: motifs jointly dated with CR and VML ($N = 25$); engravings dated solely by VML ($N = 4$); petroglyphs with CR ages alone ($N = 31$), yielding a total sample of 60 engravings. Note that three of the four petroglyphs with VML ages alone involved multiple samples and thin sections. In each case these were internally consistent.

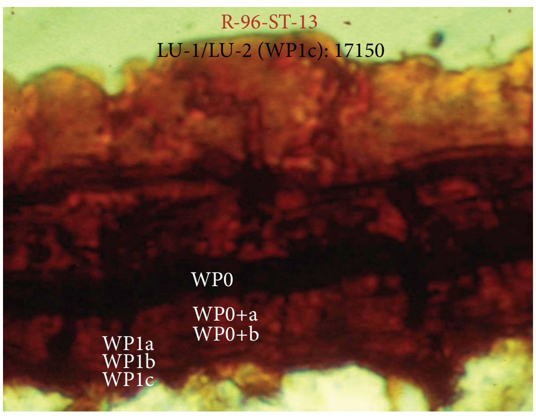
The most conservative interpretation, based solely on 16 concordant CR and VML ages verified by both analysts, indicates that petroglyph production began in the western Great Basin at least 11,100 years ago and that it continued into the last 300 years. With the exception of two earlier dating motifs, discussed below, good though not quite as certain evidence suggests that the overall age range of the petroglyphs is 12,600 to 250 yrs cal BP—from the Terminal Pleistocene to the protohistoric period. (Note that recent rock art production is independently supported by ethnographic accounts and historical subjects in the art; cf. [18].) Eleven motifs (18%) are greater than 9000 years old. Seven of these have joint CR and VML ages; two have multiple VMLs; two are solely CR dated. These eleven petroglyphs provide strong support for Paleoindian or earlier rock art production in the region.

Motif R96ST13 warrants special mention (Figure 4). As noted previously, a blind test identification of this motif, by a paleontologist specializing in Pleistocene Mojave Desert fauna, suggested that it is an extinct species of North American llama, thereby indicating that it should be early Holocene or earlier in age [18, 32, 87]. The CR age on this engraving (13,400 ± 2000 yrs cal BP) is consistent with the VML date (17,150 yrs cal BP) at two standard deviations, though one analyst qualified the VML readings as requiring additional sampling for full verification. An experimental AMS ^{14}C age was obtained on a calcium oxalate layer interbedded in the rock varnish. This yielded an age of 11,860 ± 60 yrs cal BP (Beta 90197). It provides stratigraphic and chronological concordance with the minimum-limiting VML layer and age, and the CR results. Although additional sampling is required to fully verify this age, four lines of evidence support the possibility that it represents a pre-Clovis aged petroglyph.

An additional comment is warranted concerning possible Pleistocene faunal depictions in the corpus. The second oldest CR dated representational image has an age of 11,700 ± 1000 yrs cal BP (Cima 2–5). It is a snake engraving. The third oldest, at 11,200 ± 1200 yrs cal BP (CM-7), is a bighorn sheep petroglyph. Although this species is commonly depicted in later art across almost the entirety of western North America, the bighorn has been present on the landscape since the Late Pleistocene (e.g., [89]), as have been snakes. All three of the Pleistocene-dated representational petroglyphs in the corpus, in other words, depict species that were present during that early time period.

Petroglyph LL-1, a spiral motif, is the oldest dated engraving. The cation-ratio age for this petroglyph is 14,500 ± 1300 RYBP [18]. According to one analyst, the petroglyph exhibits the 14,000 but not the 20,000 years micro-stratigraphic signature; the second suggests that this VML age requires verification with additional sampling. This petroglyph is located on boulder in a talus slope which rests on the Pleistocene channel of the Owens River, and thus the petroglyph must postdate the age of this river. The dating of this river channel indicates that it stopped flowing at approximately 16,200 RYBP [22]. The combination of the microlamination evidence and geomorphological context brackets the petroglyph between

(a)



(b)

Figure 4: Engraving R96ST13, possible extinct Mojave Desert llama, CR and VML dated to the Late Pleistocene. (a) Rock engraving; (b) VML thin section. (Engraving photo by Whitley; thin section image courtesy of Dorn.)

14,000 and 16,200 years old, a range which corresponds with the CR age of 14,500 RYBP.

Varnish dating then continues to be a useful chronometric tool in rock art research, despite the bad press it received as a result of the 1990s controversy. The application of the recently developed and verified Holocene VML calibration makes petroglyph dating all the more useful. That said, this reanalysis illustrates both the prospects and the potential problems with this approach to rock art dating. The most significant difficulty concerns the fact that the techniques are hard to learn and tedious to apply. The distribution of varnish varies, both across a single rock surface (where varnish thickness changes quickly) and across a boulder field on a slope (with the most highly developed coatings typically occurring at or near the brow or crest, diminishing towards the toe-slope; see [90]). A variety of natural processes can affect the integrity of even very small patches of varnish; for example, fungi and cyanobacteria generate acids that can very locally erode a varnish coating. The implication is that identifying the best type of varnish to sample is a technical skill beyond the training of most archaeologists. Yet sampling even by rock varnish specialists still requires a considerable amount of luck in order select microdepressions with adequately rapid growth rates, and to avoid potential complications such as acid-producing microorganisms.

The blind test field study, intended to sample and VML date petroglyphs with previous CR ages, for example, included efforts to obtain about two dozen varnish samples. Eighteen were successfully acquired by Liu but only nine of these proved to have fully intact VML sequences. These were obtained from four different petroglyphs. The VML ages on the separate petroglyphs themselves were all internally consistent. But we were only able to acquire VML samples from one previously CR dated petroglyph, among the 14 such examples at the site. The remaining VML samples were taken (in a sense) opportunistically rather than systematically: where we could find excellent varnish conditions. As potentially important as the results of this study may be, the circumstance illustrates the difficulties in using varnish dating in narrowly focused research projects.

With respect to the peopling of the Americas, the conservative results demonstrate some key points. Mojave Desert rock art production was ongoing during the Paleoindian period, prior to 11,000, and probably as early as 12,600 years ago. Less certainly, petroglyphs may have been pecked during the pre-Clovis period, potentially as early as 14,000 years ago. Assuming that the colonization of the hemisphere occurred in that general time range (e.g., as the South American dates suggest; cf. [91]), the creation of petroglyphs may have been a cultural practice that originated in the Old World, where art as early as 41,000 years old is known [92, 93]. Equally importantly, the early Mojave Desert corpus includes both geometric and iconic images, with no evidence for a chronological transition from geometric to figurative motifs, as Heizer and Baumhoff [12] speculated had occurred. This result confirms an earlier observation by Grant, who contested the Heizer and Baumhoff stylistic sequence, arguing that

> *"no such change of style can be seen. The drawings in this country cover a very long time span and for the whole period the art tradition remained remarkably stable. . .The style and subject matter of these petroglyphs vary but slightly from early to late." ([13] 16-17)*

Perhaps equally importantly, the Paleoindian petroglyph corpus contains many of the iconographic elements of the later prehistoric and ethnographic/historic rock art: bighorn sheep and geometric patterns. This supports previous arguments for general patterns of cultural continuity in the region [20, 21], although it does not preclude the possibility of subsequent linguistic change or genetic admixture, nor does it deny that substantial change over time is observable in the rock art of other North American regions.

5. Early New World Art Beyond the Mojave

Terminal Pleistocene/early Holocene petroglyphs and portable art have also been reported for a number of sites beyond the Coso Range/Mojave Desert. In the Northwestern

Great Plains of North America, Tratebas [94–97] and Francis [69, 98] have reported a series of Paleoindian period (circa 9000–12,000 cal BP) CR petroglyph ages; VML evidence supports the Terminal Pleistocene age assignments for certain of these motifs. In each case, these archaeologists have identified stylistic diversity both with later traditions and with the early art in other parts of the plains. At the Legend Rock site, Wyoming, for example, Francis and Loendorf [69] noted that three motifs dating to the Paleoindian period, one animal and two human figures, all fall outside of the range of variation of the later rock art styles at the site. More generally, Tratebas [97] has defined three distinct Northern Plains Terminal Pleistocene/Early Holocene petroglyph traditions. These include two pecked (primarily) zoomorphic traditions that are geographically distinct but stylistically similar (the "Early Hunting Tradition"), and a pecked/incised/abraded tradition that includes animals, prints, vulvas, and grooves, and may be slightly earlier in age.

On the Southern ("High") Plains, in contrast, Loendorf [67, 99] has identified an Early Incised Tradition, consisting of lightly scratched geometrics that consistently underlie pecked Early Archaic engravings in that region. Although the age of these early-incised motifs is unknown, they pre-date the Early Archaic and are therefore inferred to be Early Holocene (>7500 years) if not Terminal Pleistocene in age. Loendorf [99] has also noted the similarities between these motifs and the incised portable art from the Gault site, discussed below, which is well-dated to 9000–13,000 BP. This suggests that they may both be components of an early geometric art tradition in the Southern Plains.

A number of representational motifs in the Southwest have been identified as extinct megafauna (e.g., [100, 101]; see also [102] for California), though these are not yet chronometrically dated. Although not necessarily dating to the Terminal Pleistocene, a number of other examples demonstrate the existence of substantial stylistic variability in North American rock art, at least by the Early Holocene. A geometric petroglyph from the Southwest, for example, has been VML dated and has a minimum-limiting age of 8,100 years [103]. A deeply engraved, distinctive petroglyph, termed the "Long Lake Style" [104, 105], as well as pictographs [106], have been exposed by excavations on the Columbia Plateau. These were covered by Mount Mazama ash, indicating a minimum age of 6,800 years. VML and CR dating of a petroglyph that is stylistically similar to the Long Lake example yielded a VML age of 9400–8100 BP, and a concordant CR date of 8500 ± 1400 BP [107]. In the Great Lakes region, Steinbring [108, 109] has excavated petroglyph panels underlying Archaic deposits, which date to the mid-Holocene in this region.

Numerous claims have been made for early South American rock art which, in contrast to the North American examples, sometimes involves pictographs rather than petroglyphs, reflecting the fact that the sites in question are dry rock shelters where pigment might reasonably be preserved. Certain of the South American claims, especially for the Pedra Furada site, suggest very early inhabitation of the Americas, are controversial for that fact, and are not widely accepted (e.g., cf. Guidon and Delibras 1986; [110–113]. Despite the debate over these specific claims, there is widespread agreement, based on good empirical evidence, for other South American rock paintings as early as 10,000–11,000 years ago (e.g., [112–117]).

Much of the early South American pictograph evidence consists of small painted rock spalls and drops of pigment found in dated stratigraphic layers, rather than direct dates on parietal motifs. But chemical studies show that the excavated pigment and the rock paintings are compositionally equivalent. Citing the amount of pigment recovered per stratigraphic lens at the Monte Alegre site, Brazil, Roosevelt noted that

> *"[T]he concentration of pigment specimens in the lowest Paleoindian layers indicates that the painting tradition was already in existence when people first occupied the cave…According to the frequency of pigment in the layers, painting intensity had diminished by 10,300 BP." ([114]:39)*

A stylistically distinct, stratigraphically buried anthropomorphic petroglyph has also recently been dated, yielding a minimum limiting radiocarbon age of cal BP 10,700–10,500 and a concordant OSL date of 11.7 ± 0.8 ka–9.9 ± 0.7 ka BP on the soils overlying the motif [118]. As in North America, distinct regional stylistic rock art traditions were clearly present during the South American Paleoindian period.

Perhaps surprisingly, evidence for early portable art is more sporadic than for rock art (see [119] pp. 155–158). The Gault site, Texas, is famous for its geometrically incised chert cobbles [120, 121], dating from 9000–13,000 years ago. But perhaps more typical is Monte Verde, Chile [91, 122], dating at about 12,500 years ago, where, despite substantial excavations, no portable art was (to my knowledge) uncovered. A recent discovery of a realistically incised portrayal of a mammoth on a fossil bone from Vero, Florida [123], is at this point unique/anomalous, whether it ultimately proves authentic or not. Our best evidence for early portable art in fact is from the Northern Plains [124], perhaps as a result of the relatively large number of Paleoindian sites excavated in this region. Regardless of the reason, Northern Plains sites have included occasional examples of incised stone, bone, and ivory that, functionally speaking, include ornaments, gaming pieces, and possible fore-shafts or batons. The decorations on these specimens are predominantly (if not entirely) geometric patterns, thereby contrasting with the iconic animal imagery of the rock art motifs of the same age from this region [124].

6. Early American Art in Perspective

Our understanding of early art and symbolism of the Americas, especially as seen in rock art, will improve as our chronometric techniques are refined and more research is completed. But there is already sufficient evidence to suggest some conclusions and inferences, even if we do not yet know when the first art was produced in the hemisphere. Perhaps the most important of these, first, is that, by at least 10,000 to 11,000 years ago, substantial iconographic, stylistic, and technical differences existed in North and South American rock art. In certain cases this early art consisted of a mix of iconic and geometric petroglyphs (Great Basin); in others, engraved and primarily iconic imagery (Northern Plains; [69, 94–97]); in others predominantly geometric paintings (Amazonian lowlands; [114, 115]); possibly even exclusively incised geometric designs in another region (Southern Plains; [99]).

This evidence suggests, if not demonstrates conclusively, that substantial cultural diversity was already in place during the Paleoindian Period. The most parsimonious explanation is that this diversity developed within the Americas prior to Paleoindian times. Indeed, inasmuch as rock art and its symbolism are employed to establish, negotiate, and perpetuate religious traditions, ethnicity, ideological and gender structures, and social communications networks, among other phenomena, New World populations had differentiated into a multicultural array prior to 10,000 years ago, and probably before 11,000 YBP, if not earlier. This conclusion is substantiated by the portable art alone, best illustrated by the Gault incised cobbles [120], which further demonstrate the existence of early regional stylistic traditions—and the varying cultural and social practices and structures that they reflect.

This diversity has been archaeologically masked by the geographically widespread occurrence of a few diagnostic projectile point types, and the fluting technology that they exhibit. As Dillehay [125] has noted, analytical overemphasis on Clovis and similar points resulted in a tendency to conceptualize the early prehistory of the Americas in terms of one or just a few monolithic cultures, with a single adaptive strategy (see also [126]). A series of recent reports from far western North America has challenged this traditional view, both in terms of projectile point types and adaptive diversity (e.g., [127–129]). The art evidence supports this developing western North American perspective, reminding us of the well-known fact that culture cannot be reduced to toolkits or lithic technology alone. Substantial additional chronometric research will be required to better define our understanding of early American art and its implications, especially concerning their relationship to the spread and distribution of early projectile point types. But the existing data already indicate that, by 10,000–11,000 years ago, if not earlier, cultural complexity rather than uniformity characterized the Americas.

Based on an analogy with the European Upper Paleolithic case, second, many American archaeologists have apparently assumed that Paleoindian or earlier American art necessarily would include depictions of Pleistocene fauna, and a few comments are warranted in this regard. As noted above, a number of potential proboscidian motifs have been found, although none of these known examples have been analyzed chronometrically, and one possible depiction of an extinct camelid has been dated to approximately 13,400 years ago. Moreover, many of the animals shown in the art are in fact species that have been common on the landscape since the Late Pleistocene, such as the bighorn sheep and wapiti. Paleoindian or even earlier rock art may be relatively common in the Americas, but simply has not yet been recognized as such.

With the exception of the unique/anomalous Vero Beach incised mammoth, the early portable art from the Americas bears no real resemblance to the well-developed stone, bone, and ivory carving traditions of the European Upper Paleolithic. These were significant components of Solutrean and Magdalenian assemblages, notable for their artistic detail and realism (e.g., [130–133]). Although incised cobbles are common at the Gault site, portable art is otherwise rare at early New World localities, and, in either case, this art emphasizes simple geometric patterns rather than the naturalistic portrait style that characterizes much (though not all) of the portable art in the European Upper Paleolithic. Given the difference in the nature of the early portable arts of these hemispheres, there is no reason to expect parallels between their rock art corpora, and good reason to doubt that similarities would exist. Even though there may be occasional examples, early New World art apparently simply did not emphasize (now extinct) megafaunal species, but most likely for cultural reasons rather than due to chronology alone.

Whether an art making and using tradition arrived with the first immigrants into the Americas, or whether this tradition developed independently in this hemisphere is, of course, still unknown, though it seems most likely that art was part of the cultural baggage of the first migrant groups. When this first art was produced is likewise also unclear and will remain so, until the timing of the initial colonization is itself identified. Yet it should be noted that rock art is potentially one of the best lines of evidence for studying this very problem. Unlike buried archaeological deposits, rock art is easy to find and access. Unlike some debated lithic specimens, it is also clearly human in origin. And given its symbolic-iconographic nature, it is inherently inferentially richer than many other artifact classes, such as stone tools. As our chronometric techniques improve, rock art promises to be an increasingly valuable line of evidence for studying the peopling of the Americas.

7. Endnotes

(1) The controversy involved public accusations of scientific fraud against Dorn [37, 134–137], and received press coverage from Sydney to London. A detailed review of this controversy has been provided elsewhere [32], partly based on court records that resulted from the incident. The outcome of this controversy was the exoneration of Dorn following three lengthy investigations; a lawsuit filed by Dorn against his accusers, alleging defamation; an out-of-court settlement of the lawsuit, in Dorn's favor, following the discovery phase of the proceedings. Part of that settlement was a disclosure agreement which has prevented all of the parties involved from discussing the controversy subsequently. One unfortunate outcome of the resulting legally imposed silence, however, is that none of the parties have been able to correct the published scientific record.

At this point, it is adequate to emphasize simply that this incident only involved AMS-WRO dating, not other varnish dating methods; that, despite what was entered into the scientific literature, there was no evidence of tampering or misconduct, and Dorn was fully exonerated, and that important varnish dating research has been conducted since the controversy, including research by one of Dorn's accusers, Wallace Broecker (e.g., [5–10, 138, 139]).

(2) The disciplinary dominance and history of the Clovis first hypothesis is described by Adovasio [140]. The failure to consider the implications of any of the rock varnish dates is illustrated by almost all of the syntheses published on the peopling of the Americas in the 1980s and 1990s, and is perhaps best shown by Haynes' [119] monograph on Clovis. Like the earlier syntheses more generally, and despite the inclusion of a section specifically discussing potential Clovis era art and symbolism, the rock art varnish dates are simply left unmentioned.

(3) The chronometric constraints are primarily CR and VML thin section ages. Also included in the total and table are two experimental AMS ^{14}C ages on calcium oxalate skins that overlay two of the petroglyphs (R96ST13 and R96ST5) and two VML constraints consisting solely of microphotographic observations on the morphology of the varnish layers, distinguishing Pleistocene or Holocene production only (botryoidal versus lamellate; CM-12 and Cima 2–5). Two additional possible age indicators are listed. As discussed subsequently, motif R96ST13 was identified by a paleontologist in a blind test as a possible extinct Mojave Desert llama, suggesting a Pleistocene/early Holocene age [32, 87]. Petroglyph LL-1 is on an unweathered boulder resting on the bed of the Pleistocene Owens River. This ceased flowing at <16,200 yrs cal BP [22], providing a maximum limit for the age of this motif.

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