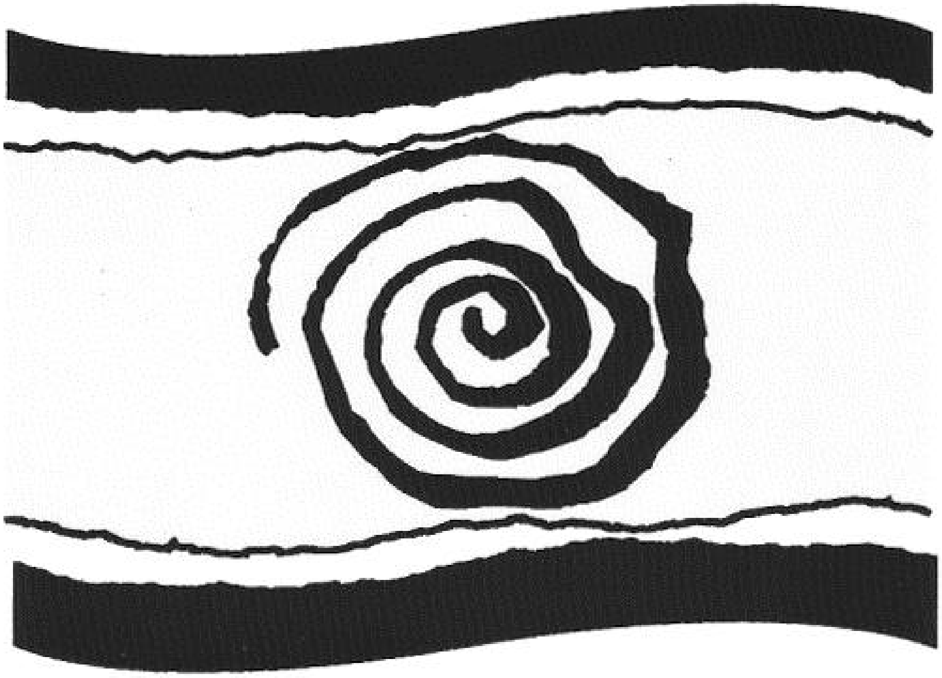
THE HUMAN JOURNEY & ANCIENT LIFE IN CALIFORNIA'S DESERTS



Edited by:
Mark W. Allen and Judyth Reed

Maturango Museum Publication No. 15
2004 Maturango Museum, Ridgecrest, California
ISBN 0-943041-08-2

EXPERIMENTAL APPROACHES TO DATING PETROGLYPHS AND GEOGLYPHS WITH ROCK VARNISH IN THE CALIFORNIA DESERTS: CURRENT STATUS AND FUTURE DIRECTIONS

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WHAT IS ROCK VARNISH AND HOW DOES IT FORM?

The California Desert is unquestionably a "classic" region for the study of rock varnish (Blake 1858, Dorn and Oberlander 1982,Engel and Sharp 1958, Eppard et al. 1996, Krinsley 1998, Laudermilk 1931, Liu and Broecker 2000, Liu et al. 2000, Potter and Rossman 1977, White 1924). Rock varnish, however, is only one of many different types of rock coatings (Dorn 1998). Although rock varnish is most noticeable in deserts, leading to its common synonym of desert varnish, this mixture of clay minerals and hydroxides of manganese and iron occurs in every terrestrial environment.

Rock varnish is analogous to a brick wall (Figure 1). Clay minerals (Potter and Rossman 1977) are like the bricks, with iron and manganese hydroxide minerals providing the mortar to cement varnish to rock surfaces. Although fossils of microorganisms occur infrequently within rock varnish (Dorn and Meek 1995, Krinsley 1998), bacteria represent the most likely mechanism of concentrating manganese (Dorn and Oberlander 1981, Grote and Krumbein 1992, Grote and Krumbein 1993, Jones 1991). Electron microscope images taken at more than 100,000x magnification reveal bits and pieces of manganese breaking off from bacterial casts, and then the manganese moves into lattice spaces in clay minerals (Dorn 1998), much in the same way that cars roll off a transport truck and move into a nearby parking space in a dealer's lot.

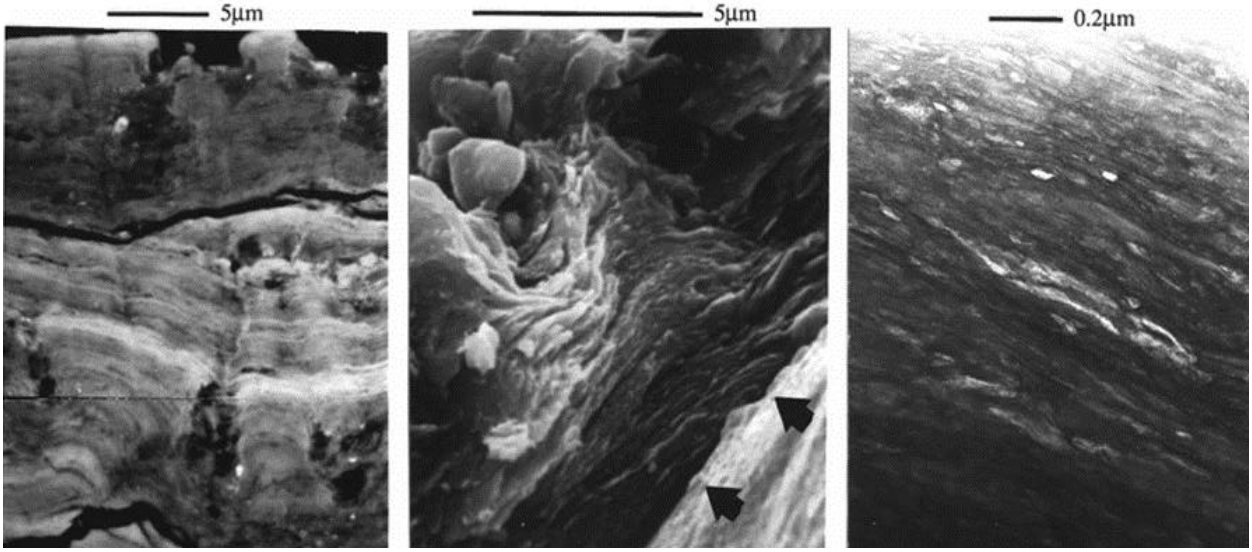

Figure 1. Different types of images, showing layering patterns in rock varnish, collected from Hanaupah Canyon alluvial fan, Death Valley. LEFT: backscattered electron image reveals average atomic number, where the bright layers are rich in manganese and iron and the darker layers are richer in clay minerals. MIDDLE: secondary electron image shows shape, with the arrows identifying the contact between the rock in the lower right and the layered varnish. RIGHT: transmission electron microscope image is at a much greater magnification, showing that there are layers within layers, where ultimately the structure of the varnish is imposed by the layered nature of clay minerals (Potter and Rossman 1977).

IS ROCK VARNISH GOOD FOR ANYTHING, OTHER THAN DATING?

Rock varnish contains extraordinary potential in assisting researchers in their studies of stone conservation, in repairing damage to sites with artificial varnish, and in studies of petroglyph manufacturing. I cover these topics in turn.

Conservation

Rock varnish reveals important clues about the conservation status of a rock art site and how to preserve a site, but the conservator must first have a thorough understanding of different types of varnishes (Dorn 1998). A few examples reveal how similar "field impressions" can yield vastly different conclusions regarding site conservation.

The presence of well-developed varnishes could either reveal excellent stability or future surface instability. If the varnish is a type formed in subaerial contexts, the site would have very stable surfaces. However, if the varnish is a type that forms within a fracture, and is now seen at the surface, extreme instability could be indicated. Granitic and sandstone lithologies, for example, are particularly susceptible to researchers misinterpreting the presence of great-looking varnish as indicative of great surface stability.

In another example, the presence of poorly-developed varnish could have two interpretations. Poorly developed varnish can be explained by rapid erosion rates of the underlying rock (Smith et al. 2000). Alternatively, poorly developed varnish can also be explained by an extreme hardness difference between a weak outer-layer of a rock and a solid inner core, where erosion of the outer layer leads to eventual site stability.

> There is even contradictory evidence on the potential of rock varnish itself to preserve rock surfaces. In some cases, varnish acts as a case-hardening agent — where the manganese and iron that is leached from the varnish penetrates into the host rock and hardens the outer shell. In other cases, varnish traps moisture — aiding decay of the underlying host rock.

Distinguishing these and other circumstances requires a solid grounding in different types of varnishes and often examination of samples with scanning electron microscopy (Figure 2).

Artificial Varnish

Artificial varnish is a chemical precipitate, sprayed on glaringly bright rock scars that can be made to look in the field like true rock varnish. The key to artificial varnish is the *in situ* oxidation of the coloring agents found in true varnish: manganese and iron (Elvidge and Moore 1980; Henniger 1995). In reality, the structure and chemistry of artificial varnish is not even close to true rock varnish; however, ongoing monitoring of early applications of artificial varnish reveals only minor chemical and textural changes in a ten-year period (Dorn 1998). Those interested in the elimination of engraved graffiti with artificial varnish should conduct site-specific and lithology-specific experimental applications before using this experimental approach to conservation. There should also be plans to revisit sites every five to ten years to re-examine fading. However, there is little danger that some future researcher might mistake artificial and real rock varnish in electron microscope tests.

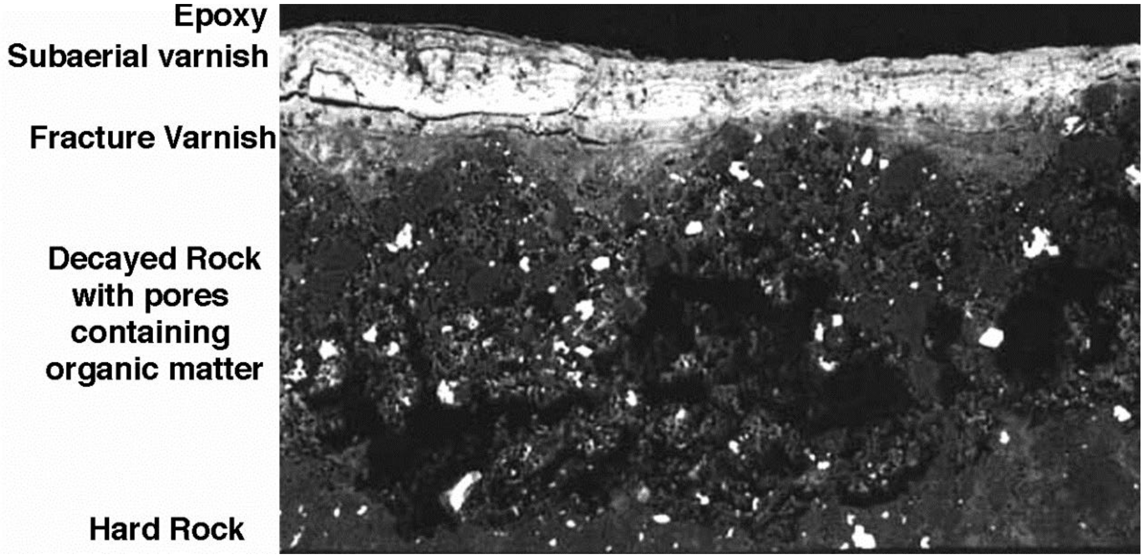

Figure 2. Backscattered electron microscope image of Death Valley rock varnish, where the width of this image is about a millimeter. This rock varnish started to grow in a rock fracture, developing an iron-rich (darker) fracture varnish. Then, after rock spalling, a manganese-rich (brighter) subaerial varnish formed. Underneath all of this varnish is decayed rock, hosting organic matter within dark poor spaces — where the initial decay and organic matter insertion could predate formation of the initial fracture varnish. In summary, rock coatings often have complex histories.

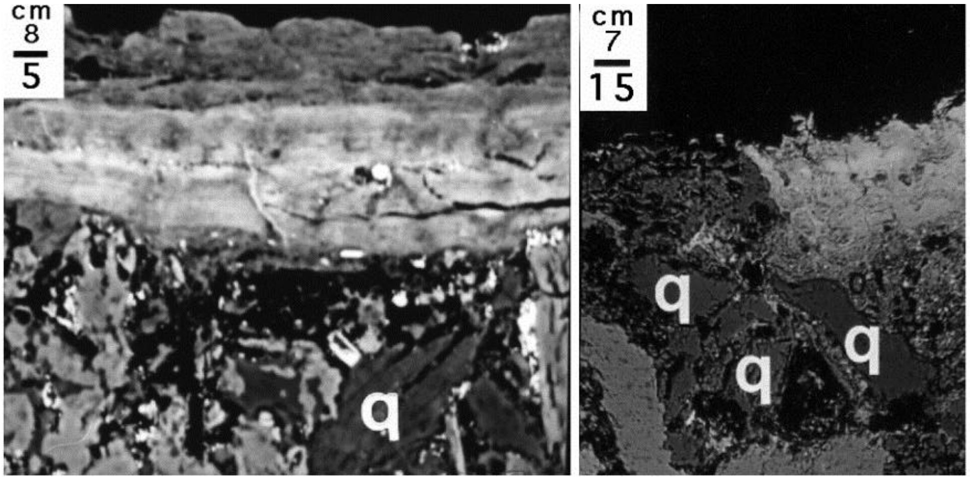

Figure 3. Backscattered electron microscopy of Coso Range petroglyph samples, where the host basalt does not contain free quartz. Thus, the presence of embedded fragments of quartz (designated by the letter “q”) reveals the use of quartz in manufacturing these petroglyphs (Whitley et al. 1999a).

Foreign Materials Analysis

Great potential exists to learn the nature of foreign materials applied to petroglyph surfaces using electron microscope methods. For example, quartz minerals embedded in grooves (Figure 3) reveals that petroglyph engravers used quartz, because the host rock contained no original quartz (Whitley et al. 1999a).

Right now, the technique is limited to petroglyphs engraved into quartz-free rock. However, it is possible to discern different types of quartz — opening the door to learning whether quartz was used to engrave petroglyphs even in quartz-bearing panels. Foreign material analysis also opens the door to learning if paint and charcoal were applied to the petroglyph. Another strategy to discriminate historic from prehistoric petroglyphs is to learn whether steel was used to carve~~d~~ engravings, because steel engraving tools can leave behind fragments of foreign material.

MICROLAMINATIONS

A quarter-century of research shows that many rock varnishes consist of layers, from the nanometer to the micron scale (Cremaschi 1996, Dorn 1984, Krinsley et al. 1995, Perry and Adams 1978). In other rock varnishes, layers eroded or never existed in the first place (Dorn 1994, Krinsley and Dorn 1991). Sometimes, layers are a product of local environmental changes (Dorn 1998, Reneau et al. 1992). In other cases, regional patterns occur in rock varnishes driven by regional climatic changes (Liu 1994, Liu and Broecker 2000, Liu et al. 2000, Liu and Dorn 1996).

Tanzhuo Liu uses a five-scale strategy to assess patterns in varnish microlaminations, running from the boulder scale to the global scale. First, Liu collects from microenvironments that are the least sensitive to local biogeochemical fluxes, since the goal is to link the varnish to regional environmental changes (Liu 1994). This avoids problems associated with collections from sites sensitive to local biogeochemical influences (Reneau et al. 1992). Second, Liu collects from multiple locales over calibration sites — to ensure that the signal replicates from boulder to boulder. Third, Liu collects varnishes from a variety of calibration sites over a wide region; for example, Liu has multiple sites throughout the Mojave Desert. Fourth, Liu collects varnishes from multiple regions over a large area such as the western United States (e.g. Figure 4). In other words, the Mojave Desert has several calibration sites within a larger regional framework. Fifth, Liu collects varnishes from multiple desert contexts, including Argentina, Israel, and China (Zhou et al. 2000). This five-scale approach allows Liu to discern site specific, local and regional microlamination patterns.

Tanzhuo Liu also uses a unique and innovative approach to making ultra-thin sections that permits careful monitoring of varnish thicknesses. A few others, such as Niccole Cerveny, use his techniques. However, traditional thin section preparation approaches result in dificulties. For example, when I assessed microlaminations (Dorn 1984~~;~~, Dorn 1992), I used conventional ultra-thin section approaches that did not yield Liu's replicability. Liu's techniques, in contrast, permit sectioning appropriate to see both large climatic changes experienced during the Quaternary (Figure 5) and less dramatic Holocene climatic changes (Tanzhuo Liu, personal communication, 2001).

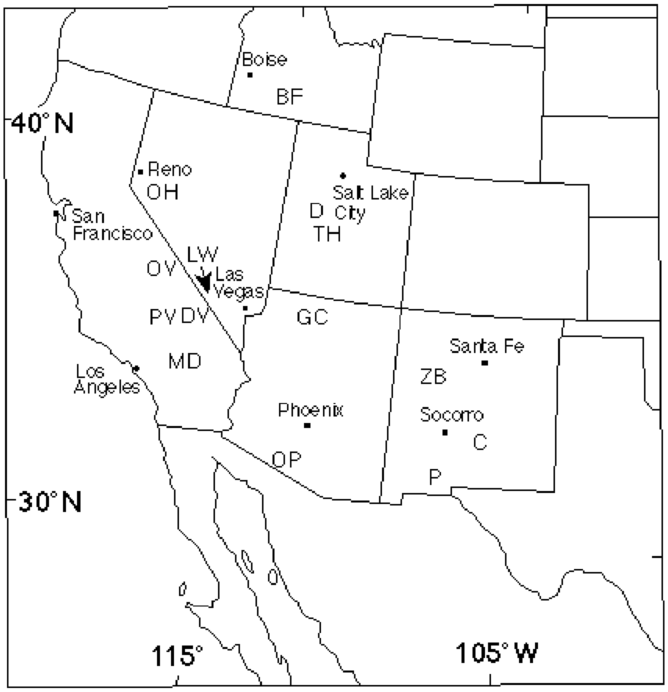

Figure 4. Geographic distribution of some of Liu's microlamination regional calibration sites. This distribution reflects more than two dozen geomorphic features that have been radiometrically dated (Liu and Broecker 2000; Liu et al. 2000). The youngest varnish calibration site is from ~1500 year old basaltic debris flow deposits in Grand Canyon, Arizona. The oldest calibration comes from a quartzite boulder in Death Valley, California ^{10}Be/^{26}Al dated at 250 ka. Other calibration sites with radiocarbon ages include ~10,000 year old Bandera lava flow in Zuni-Bandera volcanic field, the ~ 15,300 year old Dry Falls in Owens Valley, the ~14,500 year old Tabernacle Hill lava flow in Utah, the ~17,400 year old Blackhawk landslide in the Mojave Desert, and shorelines of major pluvial lakes from 10,500 to 120,000 years old.

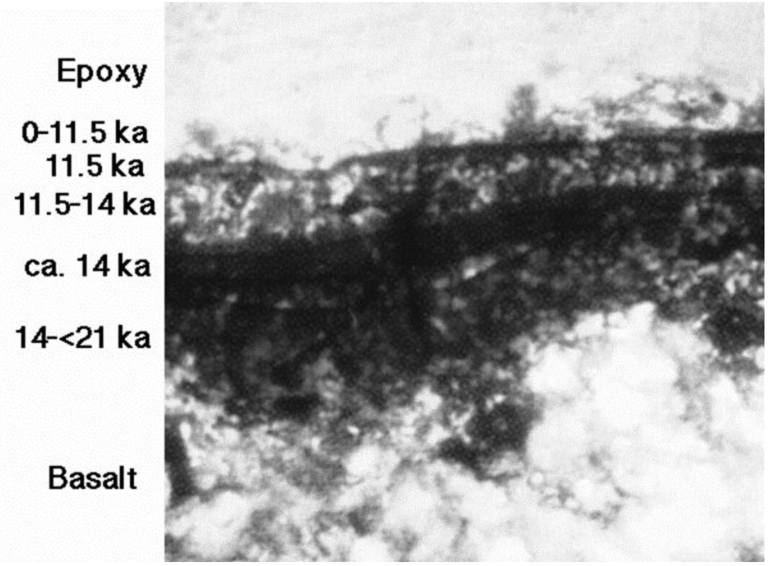

Figure 5. Microlaminations of rock varnish formed on top of a spiral petroglyph, collected with Dr. D. Whitley near Little Lake on the margins of the Coso Range. Microlaminations reveal that the varnish on the petroglyph formed after a major wet phase about 21,000 years ago, but before the 14,000 year old wet phase.

Few petroglyphs are late Pleistocene in age. Fortunately, Liu has compiled Holocene calibrations, permitting regional seriation of petroglyphs into age classes on the order of a thousand years. Using Liu's sectioning technique, my own observations reveal that some of these Holocene microlaminae appear to be common over extensive regions — such as the Mojave Desert, while other microlaminae are much more site-specific.

After completing his master's research replicating cation-ratio dating in western China (Zhang et al. 1990), Tanzhuo Liu has dedicated the past nine years, with full time support from the National Science Foundation and the Department of Energy, to understanding complexities associated with varnish microlaminations. Other researchers involved in microlaminations split time between dozens of other projects and occasional microlaminations research (e.g., Dorn 1992, Reneau et al. 1992). Having been one of those "hit and run" researchers, working on microlaminations theory part time, I state firmly that the reader must weigh very differently articles written by the primary researcher (Liu) and those who explored microlaminations in a part time fashion for a little while. In no uncertain terms, Liu's extensive background research makes microlaminations the most robust varnish-dating method. If the reader is interested in exploring the potential of varnish as a dating method at your California Desert site, microlaminations should be your first choice.

CATION-RATIO DATING

Cation-ratio dating calibrates chemical changes within rock varnish over time; the method has been applied in different ways to glacial moraines in the Pamirs (Glazovskiy, 1985) stone burial mounds in Yemen (Harrington 1986), petroglyphs in the California Desert (Whitley et al. 1999b), alluvial-fans in the Mojave Desert (Clayton 1989), petroglyphs in South Africa (Jacobson 1989; Pineda et al. 1990; Whitley and Annegarn 1994), river terraces in China (Zhang et al. 1990), and pediments (Patyk-Kara et al. 1997) and terraces (Plakht et al. 2000) in the Negev Desert.

How is it possible to obtain these positive results, while others have not been able to find replicable cation-ratio patterns in archaeological (Harry 1995, Watchman 1992) and geological (Bierman and Gillespie 1994) samples? The answer is simple. The researcher(s) did not take the time to learn how to collect varnish samples, let alone take the time to assess the importance of different varnish types in confounding their results. Failing to replicate a finding without first learning proper methodological details is certainly not unique to cation-ratio dating science (Woodward and Goodstein 1996).

Without exception, every Quaternary dating technique has proven to rely on the "art" of sample collection, where only certain types of samples yield reliable results. For example, potassium-argon dating experts use the ring of the rock as a diagnostic tool on whether to collect a sample. Cosmogenic nuclide dating experts will wander for hours before guessing which five boulders along a landform might yield the best ages. The answer for variability in cation-ratio results rests in deciding what samples to collect. Since field and laboratory criteria for sample selection are noticeably absent from most papers, it is very difficult to determine whether samples are indeed comparable. However, in speaking with A. Watchman and P. Bierman about the sorts of samples they collect, I learned that their sampling strategy differs dramatically from my own. Put another way, there is no reason why cation-ratio dating should work if incredibly small samples are analyzed, if varnishes are taken from incorrect locales, or if the wrong types of varnishes are used in the analyses.

Consider, as evidence, the discussion over why cation-ratios change over time. While some researchers saw no evidence whatsoever for cation leaching within rock varnish (Reneau and Raymond 1991), others presented explicit visual and geochemical evidence for leaching in rock varnish (Dorn and Krinsley 1991, Krinsley 1998). Reneau and Raymond (1991) researchers certainly did not make up their data; they drew reasonable inferences from the sorts of samples they collected. The obvious conclusion is that these different researchers examined very different types of varnishes. Thus, cation-ratio dating will remain a technique requiring training in learning what samples are and are not appropriate for dating.

In summary, cation-ratio dating is a powerful method for studying petroglyphs, for several reasons. First, it has been successfully replicated by many around the globe (see above). Second, blind testing of the technique is a valid scientific approach to assess method validity (Loendorf 1991). Third, sampling can be done in a way that minimizes petroglyph destruction. Fourth, the chemical measurements are relatively inexpensive. Fifth, cation-ratio dating compliments and can exist as a cross-check with varnish microlaminations in a multi-tiered approach at dating.

LEAD PROFILE DATING

Twentieth-century lead pollution contaminates ice cores (Boutron et al. 1994), tropical islands (Huang and Arimoto 1995), isolated bogs in boreal environments (Andersen 1994, Ayras et al. 1997), and even lichens in deserts (Getty et al. 1999). Thus, it was not surprising that tremendous enrichments in lead were identified in the uppermost layers of rock varnish (Dorn 1998). Researchers at Columbia University replicated these observations, noting anthropogenic pollution in the uppermost layers of many rock varnishes in the western United States (Fleisher et al. 1999). This research permits a lead-profile dating approach useful for determining whether petroglyphs are twentieth century or ancient (Figure 6).

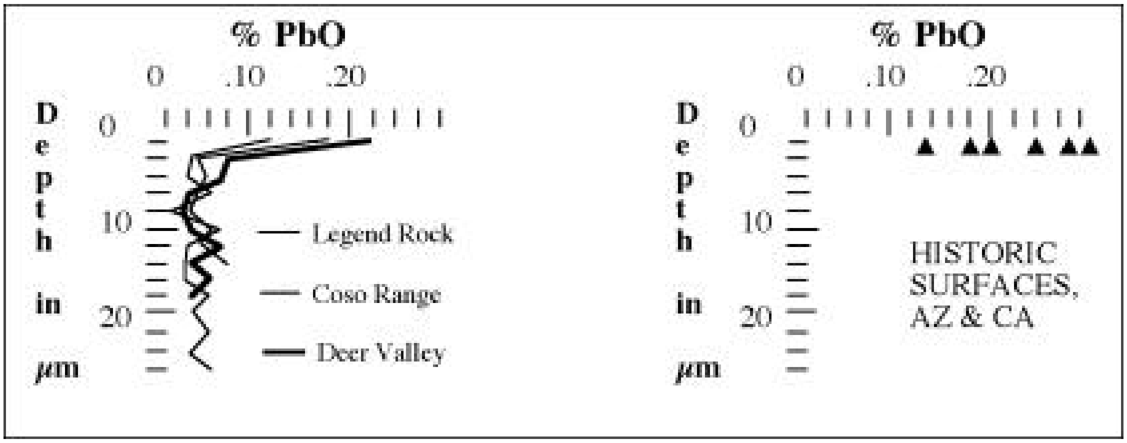

Figure 6. Lead profile dating of prehistoric petroglyphs from Legend Rock in Wyoming, Coso Range in California, and Deer) Valley, Arizona (left) and historic surfaces in Arizona and California (right).

Lead profile dating can be performed with different analytical instruments, such as the electron microbe and laser inductively coupled plasma instruments. No matter the technique, this method can help discriminate petroglyphs that pre-date anthropogenic pollution. Thus, if you are faced with a debate over whether a petroglyph is historic graffiti or prehistoric, lead profile dating may be able to determine whether or not an engraving pre-dates the extensive use of lead in automotive fuels and other sources of lead pollution.

DATING ORGANIC CARBON ASSOCIATED WITH PETROGLYPHS

Radiocarbon Dating

My call for and participation in (Loendorf 1991) blind testing of rock art dating methods led me to participate in the first and only blind testing of petroglyph radiocarbon dating with A. Watchman, conducted by Portuguese authorities in 1995 on petroglyphs in the Côa Valley, Portugal (Bednarik 1995). Watchman and I both obtained statistically identical mid-Holocene radiocarbon ages for the Côa engravings (Bednarik 1995 , Dorn 1997, Watchman 1996).

Watchman provides accurate details in 1997:

> Although [Dorn and Watchman's] methods of sampling Coa petroglyphs were different the compositions of the components dated were essentially the same. Rock chips of surface accretions and weathering rinds taken from petroglyphs contain “organic matter” of two types: modern microorganisms, charcoal and pollen debris in the soft surface accretions and fine-grained crystalline old graphite from the subsurface weathering rinds. Dates on separate fractions of these components give dates reflecting modern and old carbon (almost 30,000 years), but mixtures of the two components give results that average about 4500 years (Watchman 1997: 7)

Still, two very different interpretations of these results followed. I argued at the May 1996 American Rock Art Research Association meetings that radiocarbon dating of petroglyphs does not work (Welsh and Dorn 1997); similar statements were made in other venues (Dorn 1996a; Dorn 1996b). Watchman, in contrast, continued to argue that the radiocarbon approach worked (Watchman 1995a; Watchman 1995b; Watchman 1996).

More than four years after Watchman and I reported our findings independently, excavations against petroglyph panels in the Côa Valley, Portugal, confirmed what European Paleolithic archaeologists thought at the time of our research (Clottes 1995; Zilhão 1995; Züchner 1995): Côa petroglyphs are truly older than 21,000 radiocarbon years (Herscher 2000) [see also Archaeologically-Dated Paleolithic Rock Art at Fariseu, Côa Valley, 2000 http://www.ipa.min-cultura.pt/news/noticias/fariseu/Fariseu_uk]. Thus, in the only blind test ever conducted on petroglyph radiocarbon dating, both blind testers found similar materials, and both obtained similarly incorrect ^{14}C ages that flew in the face of known archaeological insight.

These excavation results (Herscher 2000) thus confirmed my view that there are serious problems with radiocarbon dating approaches that Watchman and I used. Figure 7 illustrates my explanation for the technique failure at Côa (Dorn 1996a; Dorn 1996b): different types of material being dated in one sample have different ages and do not compare well with independently known control ages — making the overall date for a petroglyph difficult to interpret.

Consider just one sample, as a case in point. My sample from Rose Valley, eastern California, df-2, had a bulk (mixing all different types of materials together) radiocarbon date of 13,000±100 (ETH 12813) years; the sample has subcomponents of 19,300±120 years on charcoal separated from ETH 12813, and an age far younger than 13,000 years for the dense, possibly vitrinite particles that were a part of this bulk sample. Similar ambiguity of different ages on different types of material resulted in problems at Côa. Watchman knew that some of his Coa dates contained ancient organics derived from the underlying rock, into which he says they were carved. For this reason, he says that some of them were too old (Watchman 1997:7).

Watchman could reasonably ignore my interpretation of our techniques not working — that is until independent data (Herscher 2000) confirmed my interpretation (Dorn 1996a; Dorn 1996b; Dorn 1997; Welsh and Dorn 1997). We both participated in the blind test. We both obtained statistically identical results (Bednarik 1995). We both felt there were heterogeneous materials yielding different radiocarbon ages within a single sample. Our techniques were both proven wrong (Herscher 2000).

Watchman then had several choices. He could, as I did, admit to serious problems in the entire approach to radiocarbon dating petroglyphs. The alternative he instead chose was to obfuscate technical problems with a series of false statements regarding my radiocarbon research (Watchman 2000). Rather than come face-to-face with problems in his techniques, Watchman (2000) instead redirected attention on inflammatory and false news media articles written by a journalist, Dalton:

> This intriguing case is highly controversial, even though counter arguments were offered to explain the anomaly (Dorn, 1998), because it is apparent that a natural process was not the only contributing factor by which charcoal and bituminous coal were incorporated in those varnish samples" (Watchman 2000)

By citing a non-refereed, factually false news piece in a scientific paper, Watchman's clear purpose was to infer sample tampering on my part, despite independent replication of my research by an independent Arizona State University study, and despite a finding of no misconduct by the unbiased Office of Inspector General of National Science Foundation.

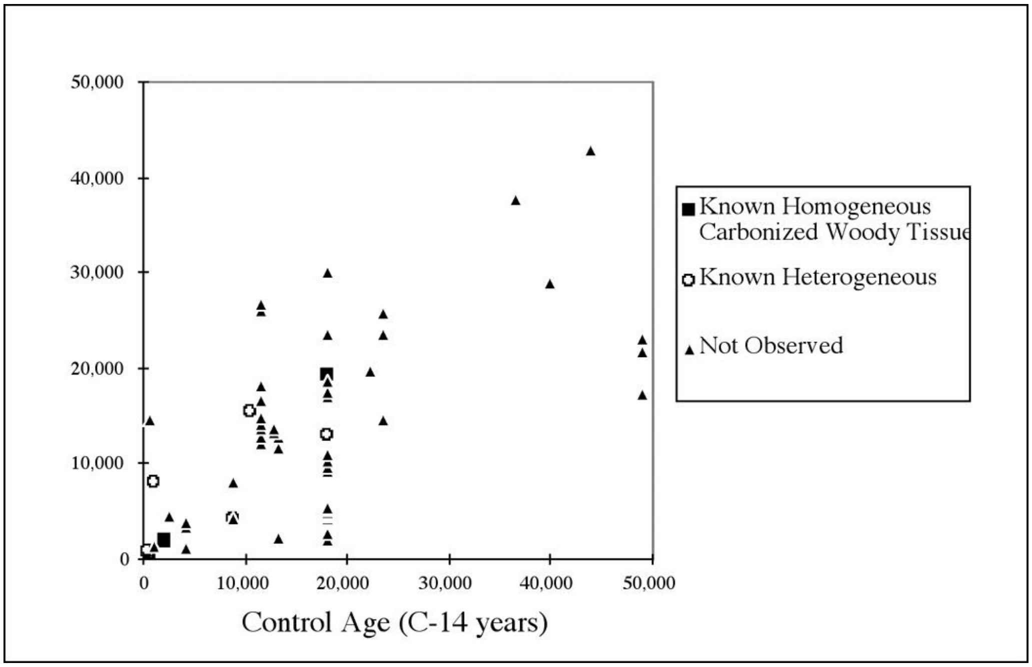

Figure 7. Compilation of radiocarbon ages of sites of known age, compared with radiocarbon ages of different types of samples extracted from rock varnish: samples known to be composed of carbonized woody tissue; samples known to be composed of multiple types of organics; and samples not well characterized for heterogeneity. Samples that are known to be heterogeneous have a large scatter. Samples that are known to be homogeneous carbonized woody tissue have the smallest scatter.

What's done is done. Watchman and I participated in the blind test. Our methods were proven false. The cat's been out of the bag since May of 1996 (Dorn 1997; Welsh and Dorn 1997), with the cat dancing on the table (Herscher 2000) for more than a year now. Slinging dirt in an attempt to redirect attention away from systematic methodological flaws achieves nothing towards improving science.

I decided to review these issues in this paper with the sole intent of avoiding any confusion in the "take home message" to those interested in dating petroglyphs in the California Desert. There is clear evidence that organics associated with petroglyphs are in an open system. This means that carbon older and younger than petroglyphs work their way into petroglyph samples. Any attempt to use radiocarbon dating on petroglyph organics should be done with the full realization that the dates likely have no clear meaning. Those attempting to date petroglyphs using radiocarbon should not interpret those radiocarbon ages as anything other than experimental data for basic research into carbon cycling on rock surfaces. It may be possible someday to resolve uncertainties. However, it is my belief that years of basic research with substantial support will be needed to begin to work out systematic biases in radiocarbon dating on petroglyphs.

OCR Dating

The organic carbon within the varnish itself typically yields radiocarbon ages that are modern to a few hundred years old (Dragovich 2000; Staley et al. 1991), a result that originally led me to explore the use of subvarnish organic matter in radiocarbon dating (Dorn 1998). After the Côa, Portugal, blind testing revealed flaws in the radiocarbon dating of petroglyphs, two research pathways logically follow: (a) walk in the footsteps of those working on bone radiocarbon dating by trying to isolate the part of the carbon system that is closed and reflects the true age of bone (or rock varnish) formation; (b) or admit that the organic carbon system is wide open and work with a dating method for the carbon that does not assume a closed system.

In light of the clear evidence of an open system, I turned to an open-system approach to dating carbon called OCR dating (Frink 1992; Frink 1994). I first replicated the OCR technique independently with geomorphic samples in Peru (Dorn et al. 2000); at the same time, the OCR dating technique successfully passed a harsh blind test in the context of an Australian rock shelter (Harrison and Frink 2000).

Thus, I decided to try OCR dating on (a) disseminated organic matter found within vesicular soil material in reformed geoglyphs and (b) disseminated organic matter found within rock varnish associated with geoglyphs and petroglyphs. I used a cross geoglyph and the anthropomorphic geoglyph from the Ripley Geoglyph site (Figure 8), collected with Jay von Werlhof and Harry Casey, and samples collected with Dr. D. Whitley from a spiral petroglyph in the Coso Range (see Figure 5).

Figure 8. Ground photograph of the sampled Ripley geoglyphs, courtesy of Harry Casey.

The OCR approach is well tested in humid soil contexts, but it is extremely experimental in arid regions. Coefficients used in the OCR formula have not been calibrated for desert soils or desert rock coatings. Thus, please do not use these "OCR dates" as real numbers to be employed in developing archaeological theory. The OCR ages presented here should only be considered relative ages — placed in a numerical context only for the purposes of illustrating some idea of the scale of numerical differences between OCR measurements.

Figure 9 presents OCR ratios and relative ages for vesicular soil from sampled Ripley geoglyphs. sIn other words, the Av horizon of the soil underneath the reformed desert pavement was treated to extract data displayed in Figure 9, where the OCR dates were calculated using Frink's (1992, 1994) OCR formula coefficients for humid soils. The data points in Figure 9 represent five samples taken from the cross and anthropomorph geoglyphs, while seven samples came from adjacent natural pavement. The technique correctly places geoglyph ages as younger than the adjacent natural pavement. It may be a case of the blind leading the blind, but thermoluminescence ages for soils on well developed desert pavements in the Mojave Desert yield similar ages to these OCR dates for natural Av soil horizon under desert pavement (McFadden et al. 1998).

OCR ratios and ages were also measured for varnishes formed on top of the natural pavements and the cross geoglyph. In the case of the cross geoglyph I scraped layers from three separate varnish samples, but the varnish was so minimal that only two layers could be collected. In addition, four layers were extracted from a spiral petroglyph in the Coso Range (cf. Figure 5). The process of scraping layers is subjective (Bard et al. 1978), but provides an idea of relative trends in the open system for organic carbon within varnish layers. Results are presented in Figure 10, keeping in mind that OCR ages are only relative.

One way to interpret Figure 10 is in terms of OCR values (vertical scale) reflecting the open nature of organic carbon within rock varnish. Younger organic matter is constantly flushed through the varnish, all while organic matter undergoes diagenetic alteration. The uppermost layers in the varnish, thus, should have the lowest ratios, because organic matter has undergone the least amount of diagenesis (change towards more stable forms of carbon) over time. Thus, it makes sense that the lowest layers in the varnish should retain the most mature forms of organic carbon and hence the highest OCR values. Similarly, the oldest OCR ages are found in the lowest layers of varnishes, because there is the greatest retention of the older, more altered, carbon.

Figure 9. Relative ages of vesicular soil samples collected from the Ripley geoglyph site, Colorado River Terrace, far western Arizona. The OCR ages are calculated with the OCR formula used in humid and pedogenic contexts, and they are not yet calibrated for hyper-arid soils.

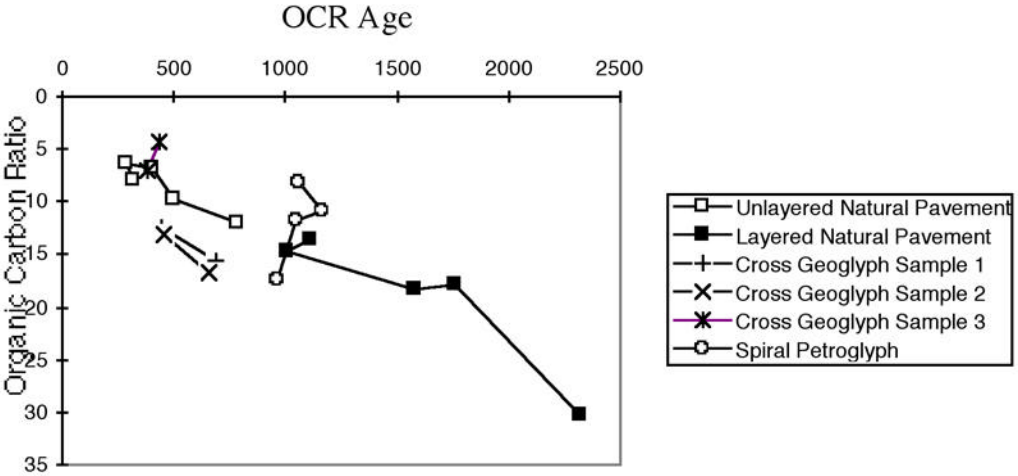

Figure 10. Organic carbon ratios (OCRs) and relative OCR ages of varnish samples collected from varnish layers, where measurements for different layers are connected by lines. For each line, OCRs generally increase with depth in progressively lower layers in varnish scrapings. Natural pavement and cross geoglyph samples were collected from the Ripley Geoglyph site, and the spiral petroglyph was collected from the Coso Range (cf. Figure 5).

The hope of this research is that it might be possible at some point to model OCR ages much in the way that mean residence time (MRT) radiocarbon ages on soil A-horizons are modeled to record the onset of soil formation. The key will be obtaining these OCR depth profiles at locations where ages are known independently, through blind testing, prior to the onset of modeling research.

CONCLUDING THOUGHTS ON RESOLVING UNCERTAINTIES

The future of varnish research in the California Desert and elsewhere continues to be hampered by a "hit and run" research tradition with two characteristics. First, very few researchers focus on rock varnish long enough to understand its varieties and the necessity to use multiple analytical approaches; rather, these researchers take an analytical technique or two they happen to be familiar with and apply them to rock varnish. Second and far more importantly, many researchers fail to comprehend that their initial visual impressions are untrained and limited; hence, they operate as though they believe that all rock varnishes are the same. This is not true (Dorn 1998), much in the way that not all lithics or pottery fragments are the same. The literature on rock varnish and varnish dating is peppered with papers written by researchers who grab a few samples, do not characterize or communicate the type of varnish analyzed or collected — and generalize their findings to the entire field. Certainly, this approach towards research is not unique to rock varnish (Fuller 2000), but it does plague the field. On the flip side, science must be replicable, and "hit and run" drivers - no matter how poorly intentioned and poorly trained to go behind the wheel - do help others isolate potential complications and communicate more clearly methods and interpretations.

A far more serious issue is the ethical imperative ignored by academic archaeologists. As a geographer looking into the foreign field of archaeology, I am utterly dumbfounded by academic archaeologists living on the doorstep of California's Deserts — yet focusing their attention on research topics that are in no immediate or even long-term peril of destruction. Unlike resource managers and contract archaeologists attempting to understand, protect, and salvage what they can in the wake of tremendous population pressures, academic archaeologists have the freedom to pick the pleasure of their research focus. Please, for the sake of future generations, I beg academic archaeologists to encourage their students to work towards understanding rock art before it disappears forever. Future academic archaeologists will surely condemn inactivity on rock art research as one of the greatest tragedies of the discipline — literally letting a golden treasure slip underneath collective noses. Future academic archaeologists surrounding the California desert will most assuredly highlight inactivity as evidence that their predecessors were little more than range animals led by academic shepherds concerned only with winning little internal disciplinary squabbles — what Fuller (2000) calls "normal science". I hope that today's academic archaeologists develop the internal ethical compass to work towards understanding our collective cultural heritage before it is forever lost. These are the thoughts of an outsider looking in.

As a geographer with a career focused on the geography of rock decay, I feel an ethical imperative to discern as much information as possible from the global cultural heritage of rock art before it disappears from the onslaught of anthropogenic destruction. Thus, I will continue to urge students and colleague researchers to develop and test experimental approaches to work towards understanding the human condition through the nexus of art, religion, and science exhibited in rock art (Whitley et al. 1999a,b).

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