BEYOND TAPHONOMY: PEDOGENIC TRANSFORMATIONS OF THE ARCHAEOLOGICAL RECORD IN MONUMENTAL EARTHWORKS

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ABSTRACT

Mesolithic and later peoples acted as aggradational and erosional geomorphic agents – crafting monumental earthworks including enclosures, mounds, and earth figures in temperate, frigid, and arid environments. Taphonomy studies processes emplacing organisms into the fossil record, and taphonomic laws governing geologic processes underlie conventional archaeologic interpretations of artifacts associated with monumental earthworks. Taphonomic explanations, however, may render misleading interpretations when such explanations fail to consider temporal and spatial scale, and ecological setting. Our paper focuses on temporal, scalar and ecological information embedded in superposed aerobic soils and rock surfaces whose dynamic autopoietic systems and metabolic processes affect the organization of associated artifacts. Studies from Arizona, Louisiana, Texas, and the Czech Republic exemplify pathways by which pedogenic and weathering processes constrain spatial and temporal interpretation of earthworks.

Mesolithic and later peoples acted as aggradational and erosional geomorphic agents – constructing and maintaining monumental earthworks including enclosures, mounds, and earth figures in temperate, frigid, and arid environments. Such earthworks are important artifacts of culture, and constitute major expressions of human behavior. Thus, it is important that these earthworks are properly understood within their spatial, temporal and historic contexts to facilitate appropriate anthropological conclusions.

Enclosures and mounds are characterized by the accumulation of sediments, and sometimes rocks and wood, into an ordered enclosing wall and round, oval, or rectangular tumuli. Earth figures display artistic or symbolic motifs on the land by disturbing soil surfaces, and are represented by both negative and positive relief on landscapes. Earth figures include both geoglyphs, sometimes called intaglios and rock alignments. Geoglyphs are engravings on the earth's surface made by scraping back darker surface gravels to expose lighter-colored subsoils (Clarkson 1990, 1994; Silverman 1990). Rock alignments, in contrast to geoglyphs, form positive relief by accumulations of larger rocks in patterns contrasting with smaller rocks forming the underlying surface (von Werlhof 1989).

Taphonomy is the study of processes responsible for inclusion of organisms into the fossil record, and how these processes alter fossil form or context. Cultural material, or artifacts, are substituted for organisms in archaeological adaptation of geological taphonomy. In both cases, taphonomy is currently used to explain original living context or use context and processes that acted on that fossil or artifact in both time and space.

Generally, cultural material contained within, on, or under, monumental earthworks determines temporal context. Taphonomic laws governing geologic processes underlie interpretations, defining whether the artifacts found within are of primary deposition, associated with the contemporaneous culture or intrusive material of later cultures, or of secondary deposition, belonging to a people whose cultural material was inadvertently included along with the construction material. Without clarity of these relationships, the information has, as describe by the Mayanist Alfred Tozzer, "... an inert quality, a certain spinelessness when unaccompanied by a more or less definite chronological background" (1926:283).

The most important principles of geologic taphonomy used in archaeological interpretations of monumental earthworks define physical context and describe condition (physical and chemical change). Cultural artifacts and geologic fossils may be comparable as objects that have moved out of a living, biological context to be deposited along with other sediments. However, differences in physical and temporal scaling between geologic and cultural processes are too great to be ignored. Geological taphonomic laws designed to explain processes of fossil inclusion, preservation, and diagenesis within a subaqueous environment cannot be used to explain the processes of artifact inclusion, preservation and diagenesis within an aerobic superaqueous-environment without consideration for these contextual differences. If we limit our interpretation of archaeological records strictly in terms of such uncontextural stratigraphic processes, then we can never truly understand these records.

General assumptions of end-products of diagenesis on geologic time scales may not be appropriate

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at anthropological time scales. Organic carbon within oxic environments is recycled at time scales in excess of one-million years. However, at the anthropological scale (10 to 100,000 years) organic carbon may be found in various forms of diagenesis ranging from nearly unaltered organic matter to humus, inertinite, lignite and vitrinite. The Tule Springs site, in southern Nevada provides an example of such a diagenetic transition:

> "...prehistoric animal bones were associated with apparent hearths dating back more than 28,000 years. What (C. Vance) Haynes found instead was that the charcoal in the hearths wasn't charcoal at all but decaying vegetation on its way to becoming coal" (Parfit 2000:52).

Scaling also affects our assumptions of physical end results of bioturbational processes. Evidence of bioturbation of super-aqueous landforms are subtly expressed and seldom identified in the geological record. In fact, other than unusual paleosols subsequently buried and lithified subaqueously, super-aqueous bioturbational processes are virtually invisible in the geologic record. Yet bioturbation creates uncertainty in interpreting many, if not all archaeological sites.

Soil genesis, inclusive of horizonation and haploidization, occurs at time scales varying between 10 and 10,000 years. Furthermore, soil genesis specifically includes processes that occur in aerobic, subaerial environments and on the surfaces of rocks (Jenny 1941, Vinogradov 1963, Ha-mung 1968, Bolotina 1976) that form rock coatings and the weathering rinds of rocks used in monumental earthworks (Krumbein 1988, Krumbein and Urzi 1993). Thus, we contend that discussion of taphonomic processes for archaeological studies are better understood through analyses of pedologic processes.

The first part of this article considers soil processes affecting archaeological taphonomy as dynamic open systems. Second, we introduce OCR Carbon Dating as a procedure to characterize autopoietic evolution of Monumental Earthworks. The third section focuses on analyses of macroscopic and microscopic case studies of empirical data from: mounds at Watsons Brake site in Louisiana and Morse site in Texas; ramparts at a Neolithic site in the Czech Republic; vesicular soil horizon formed on geoglyphs at the Ripley, Arizona site; and then weathering rinds and rock coatings at the Ripley geoglyph site. We lastly conclude that OCR dating offers unique insight into monumental earthworks. Although our study sites are distributed geographically, the lessons learned in these different environments are applicable throughout Arizona and Nevada archaeology, physical geography, and soil contexts.

SOIL PROCESSES AFFECTING ARCHAEOLOGICAL TAPHONOMY

Soil evolves in a system open to energy and matter. Soil is not static, but constantly undergoes biochemical and physical changes according to its specific organizational design (Johnson and Watson-Stegner 1987, 1990; Johnson et al. 1990; Johnson and Hole 1994). This design is unique to each soil body, and depends on interaction with its specific environment. Archaeological artifacts and features contained within, or constructed from, soil are reorganized from original cultural contexts according to the soil's organizational design (Butzer and Hansen 1968, Shlemon 1978). Thus, an understanding of the soil's organization facilitates interpretation of physical and temporal contexts of monumental earthworks, and artifacts contained within them.

Traditional geoarchaeologists and soil geomorphologists view soil development or pedogenesis as resulting from two opposing processes: horizonation, the tendency to differentiate into separate horizons, and haploidization, the tendency of turbations to homogenize the soil (Buol et al. 1980). This bifurcation of soil processes into biochemical and biomechanical processes is more the result of competing philosophies than an inherent characteristic of the soil's organizational design (Johnson et al. 1987, Johnson and Hole 1994, Johnson 1993).

As both horizonation and haploidization are evident in all soils, it is more productive to view these processes as manifestations of inter-independent subprocesses of the soil's organization. Particle-size differentiation, culminating in the development of argillic horizons (illuviated clay accumulation forming a horizon) and stone lines (illuviated coarse particle accumulation forming a horizon), is one such subprocess of organization found in soils. The genesis of argillic horizons follow a process of biochemical weathering of mineral soils into clays (Mulder and van Veen 1968, Malla and Komarneni 1989), and the movement of these clays from the A and E horizons (zones of elluviation) into the B horizon (zone of illuviation) (Birkeland 1984). Stone lines result from biomechanical, or bioturbational, events that translocate coarse clastics from the A to the B horizon (Johnson 1992).

Examination of mature soils found in temperate regions reveals one or both of these textural horizons at the lower reaches of the B horizon. Their location at the boundary of both biochemically and biomechanically active soil suggests that these soil horizons effectively describe the lower spatial limit on the domain of pedogenic processes (Birkeland 1984, Cremaschi and Busacca 1994). The biosphere may be thought of as providing the upper limit of this domain (Krumbein and Dyer 1985). In areas of extreme temperatures (both hot and cold) and limited rainfall, the soil body is challenged to produce this upper vegetative boundary (Rundel 1978, Dixon et al. 1984, Dixon 1986). In these areas, coarse material forms surface stone lags (patterned ground and desert pavement) and/or surface and near-surface accumulations of calcrete and rock coatings (Washburn 1969, Mabbutt 1979, Chitale 1986, Verheye 1986, Amit et al. 1993, Dixon 1994, Dorn 1998).

The texturally and botanically demarcated domain of pedogenic processes also describes the portion of soil where organic carbon is deposited, diagenetically altered, and sequestered for a geologically short period of time. Within this domain, new (young) organic carbon enters from the surface (litter) and near surface (roots) (Phillips 1963, Danin et al. 1987, Bruand et al. 1996, Jackson et al. 1997), and slowly moves toward the developing stone line and/or incipient argillic horizon. As organic carbon moves it is continually being oxidized and otherwise altered by a variety of soil microbial communities and biochemical processes changing fresh organic matter into humus, inertinite, lignite, vitrinite, and other macerals (e.g., Chitale, 1986, Shuichi and Ryoshi 1989, Esterle and Ferm 1994, Jones 1994, Siffedine et al. 1994, Guo and Bustin 1998, Lichtfouse et al. 1998, Thery 1998, Lichtfouse 1999a,b).

The concurrent development of both biochemical and biomechanical soil horizons, that effectively sets limits on the domain of pedogenic processes, indicates a self-organizing, system (Phillips 1995). Self-organizing systems, or autopoietic systems, are defined as living systems composed of a network of production processes where each component participates in the production or transformation of other components in the network (Maturana and Varela 1980). Pedogenic processes, in addition to the example of textural differentiation occurring within this defined domain, include diagenesis of organic carbon, development of ped (soil aggregates) structure, weathering of clays and sesquioxides (iron, manganese and aluminum oxides) from mineral sediments, fixation of phosphates and nitrates and other organic derived material, expulsion of wastes such as carbon dioxide, ammonia, and various salts and metals, that together act to define and create soil. These various process are essentially metabolic, describing the production and transformation components of the soil network.

These metabolic processes, easily recognized in temperate soils, are less obvious in desert soils due to the paucity of macroscopic surface vegetation and limited seasonal rainfall. However, desert soils appear to demonstrate the same metabolic processes described for temperate soils. Organic matter, synthesized by lichen, algae, fungi, cyanobacteria, and other organisms such as annuals and perennial plants, deposits, diagenetically alters, and sequesters for a geologically short period of time. The elimination of wastes, clay weathering, and the translocation of both coarse and fine textured material, are concurrent subprocesses with organic carbon metabolization. However, due to environmental factors, these various subprocess manifest in different form. Because soil is unable to produce a protective surface boundary of plant material, alternatives such as cryptogamic crusts and desert pavements (stone lines defining the uppermost boundary rather than a lower boundary) may be seen as defining the domain of the soils physiological processes.

Although soil scientists naturally focus on centimeter-scale pedogenesis, the alteration of bedrock occurs at sub-millimeter scales. Weathering-rind formation on rock surfaces is analogous to processes seen during incipient soil formation on bedrock (Krumbein 1988; Krumbein and Urzi 1993; Jones 1994). Rock coatings evolve from the same biological and chemical processes as eolian cumulic soils such as loess, where climatic change moderates and controls ongoing deposition of rock coatings (Dorn 1998).

Following their initial creation, earth figures evolve along analogous pathways as do the soils and sediments associated with enclosures and mounds. Pedogenic soils, and soil-like entities form on and within earth figures, although at a finer physical scale than that seen on enclosure and mound sediments. Open-system perspectives, such as autopoieses, offer a means for understanding the micro and macro taphonomic processes encountered with a full range of monumental earthen architecture.

As complex dynamic systems, temperate and desert soils as well as rock coatings, exhibit self organization and self definition. We do not view soil, and soil-like bodies as the passive end result of "five factors of soil formation" (Dokuchaev 1967 [1898], Jenny 1941). Instead, soil bodies create themselves through interactions as autopoietic systems in tandem with these "five factors." Self-creation, or autopoiesis, of soil may be described in terms of respiration, consumption, metabolization, waste elimination, and boundary formation processes.

Taphonomic interpretations that do not take into account these essentially physiological processes assume a static nature to monumental earthworks that simply does not exist. An assumption of static pedogenesis is particularly problematic in archaeology because the objects of study are coarse particles (artifacts), that affect and are affected by metabolic processes of the soil, or organic inclusions (ecofacts) associated with rock coatings. Assumptions of cultural associations between artifacts and occluded ecofacts that are based entirely on static descriptive approaches (e.g., Harris Matrix, see Harris 1979) can only be effective with non-pedogenic sediments (fill). Within dynamic open systems, such static approaches of analysis describe patterns that are the result of the soil's physiological processes, and not cultural patterns relevant to past cultural expressions.

THE OCR CARBON DATING: A PROCEDURE FOR CHARACTERIZING THE AUTOPOIETIC EVOLUTION OF MONUMENTAL EARTHWORKS

The OCR Carbon Dating procedure is an experimental approach that measures site-specific rates of biodegradation of organic carbon, either as soil humic material or as charcoal (Frink 1992, 1994). The effect of biochemical degradation is measured by the OCR_{RATIO}, a ratio of the total organic carbon to the readily oxidizable carbon in the soil. Put another way, the pool of readily oxidizable carbon decreases at a greater rate than the total organic carbon through time. The OCR procedure assumes that carbon compounds change and evolve through a set of processes usually called organic carbon diagenesis.

The foundation of the OCR procedure rests on differential rates of biochemical degradation – varying within specific physical and environmental contexts of soil samples. For example, Lichtfouse et al. (1995) found distinct pools of soil carbon with humic acids having a faster turnover rate than bulk organic carbon, with humin having an even slower turnover rate. Some organic substances in soils and sediments are lost rapidly, while others undergo such a long-term turnover that they become "molecular fossils" (Lichtfouse 2000).

The OCR Carbon Dating procedure differs epistemologically from radiometric carbon dating procedures. Radiometric carbon dating must necessarily rely on a closed system, for dating procedures measure the radioactive decay of carbon-14 atoms through a purely physical process. The OCR procedure relies on an open system, where some organic carbon is lost rapidly through a fast turnover rate while other types of organic carbon have much slower turnover rates. Thus, the OCR_{DATE} is not a direct measure of an intrinsic characteristic of the soil organic carbon. Rather, the procedure offers a way to model the dynamic and nonlinear soil system (an open system) through time, and relative reactivity of soil organic carbon within that system. Dynamic systems resist entropy by organizing and maintaining themselves at a distance far from equilibrium. The OCR procedure, thus, describes an evolving pedogenic system.

While radiocarbon dating is appropriately "calibrated" through the use of tree rings and coral experiencing no evident diagenesis, organics extracted from soil archaeological contexts rarely fit such perfect conditions. Those archaeologists using radiocarbon dating must assume that their samples behave totally and completely like tree rings and coral by believing their samples are unaffected by diagenetic processes. Consider, for example, the relatively simple case of ancient textile fragments that may or may not have been exposed to a complex soil system. Even though a cursory optical examination may reveal no apparent alteration, such qualitative judgments can miss microbial alterations that would alter a radiocarbon date (Ljungdahl and Eriksson 1985). When radiocarbon samples are extracted from pedogenically active soil, potential complications increase dramatically. A study on the role of chemical pretreatment for soil charcoal samples, for example, revealed severe problems with charcoal dating in soil settings:

> "Results yielded an inconsistent chronology, affected by contamination with younger humic materials...A more consistent and older chronology was achieved using AMS dating of rigorously pretreated samples of fine-grained charcoal" (Gillespie et al. 1992:29).

Our point is certainly not that radiocarbon dating is invalid. Far from it. Accurate and precise ages ensue when samples are carefully prepared by laboratories employing experienced personnel focused on careful laboratory pretreatment. Without such pretreatments the radiocarbon age will reflect a complex signal of old (biodegraded) and young (open system additions) carbon cycling through soil. The very need for chemical pretreament demonstrates the principal behind dates calculated by the OCR procedure – that complex organic matter diagenesis occurs in open systems. In other words, if your organic archaeological samples are chemically pretreated for radiocarbon dating, the dating laboratory explicitly recognizes the open nature of the soil organic matter system.

The OCR procedure is experimental, because of inadequate understanding of organic carbon transformations. For example, there is "poor knowledge of the structure and formation of humic substances" that

> "involve at least three processes: selective preservation of microbial, straight-chain biopolymers; physical encapsulation of apolar substances by weak forces; and

> chemical binding by covalent bonds" (Lichtfouse 1999a:385).

Contemporary data reveal pools of differential preservation of humin-bound molecules over time (Lichtfouse 1999b). In another study, Lichtfouse et al. (1998:411) observed soil pathways of "microbial biosynthesis of highly aliphatic cell walls which are chemically and physically resistant to biodegradation"– exemplifying yet another form of differential preservation among soil organic carbon. The above research offers explanation for differential preservation of organic carbon observed empirically by Frink (1992, 1994), confirmed through blind testing (Harrison and Frink 2000), and then later replicated by Dorn et al. (2001). Certainly, both OCR and radiocarbon dating of soil organic carbon can only be refined through additional studies of processes moderating exchange rates in organic transformations in the archaeological contexts.

The OCR procedure takes an empirical approach to measuring the flow and stabilization of soil carbon by accounting for known and measurable variables influencing pedogenic evolution of soil. The OCR_{DATE} is determined through a systems formula that empirically adjusts for biological influences resulting from oxygen, moisture, temperature, carbon concentration, and soil reactivity (Frink 1994). Residual influences on this system are included through a statistically derived constant.

In summary, the OCR Carbon Dating procedure describes physiological processes of soil bodies and their effect on taphonomy of artifacts and occluded ecofacts. Variables in the OCR formula describe related production processes in soil networks that participate in the autopoietic production or transformation of soil bodies. Close interval sampling along a vertical soil column helps define the archaeological and temporal contexts of artifacts and associated features. A comparison between samples in a soil column reveals certain individual processes and their relation to, and participation with, other processes. Comparison of soil textures between samples shows development of boundaries through evolving stone lines (coarse particles) and incipient argillic horizons (fine particles). Soil reactivity (pH), total organic carbon and the OCR_{RATIO} describe consumption, digestion, and waste elimination processes. The variables analyzed in the OCR procedure are doubly pertinent to the issue of taphonomy in monumental earthworks, for they reflect a soil's recovery following such anthropogenic events of turbation.

Human occupation alters pedogenic processes by: introducing additional organic matter (middens); changing pH from acid or base loading; adding coarse particles (in the form of artifacts, or as the result of winnowing away fine particles from the surface due to vegetation removal and foot traffic); and performing activities (both physical and chemical) that increase weathering of clays (Robert and Tessier 1992) from surface or near surface mineral soils through physical abrasion and removal of the protective vegetative, or in the case of earth figures, the surface soil or stone line boundary. Immediately after deposition, human artifacts enter the pedological sphere, where they are chemically and physically altered by soil metabolic processes. These pedological events (cultural turbations) remain evident in soil profiles as secondary evolving stone lines, incipient argillic horizons, and uncharacteristic (when compared to the normal trend of the simple soil profile described above) values for pH and total organic carbon.

Human occupation may further disrupt pedogenic processes of a soil through construction of monumental earthen architecture such as enclosures, mounds and earth figures. In these cases, soil, sediments, or both are removed from original pedogenic or depositional contexts and piled up in a chaotic fashion as sediments (fill), or, upon removal, expose fresh unweathered material which immediately resumes pedogenesis as a new soil body, beginning at its interface with the atmosphere and subsequent biosphere. Beneath this new soil of aggraded earthworks lies fill sediments, and the now buried original soil, which being deprived of fresh organic carbon and oxygen, ceases its metabolic processes. The buried soil remains dormant (pedogenically static) until the evolving pedogenic front from the overlying surface soil reaches it. At that time, the overlying soil body's metabolic processes incorporate the buried soil, thus reorganizing it according to the new soil's physiology.

CASE STUDIES ON TAPHONOMIC EXPLANATIONS WITHIN PEDOGENIC SCALES

Mounds as Pedogenic Temporal Discontinuities

An autopoietic perspective on anthropomorphic mounds sees soils that were once pedogenically alive, but are now mounded into a heap of pedogenically dead mineral and organic corpses. Concomitantly, after the last basket load of fill topped the pile, growth begins in a new soil body. The extent and duration of this new soil body's growth can be charted using the variables from which OCR_{DATES} are calculated. Viewing soils and the associated monumental earthworks as autopoietic open-systems permits researchers to distinguish the new soil from characteristics inherited from the former soil.

Postabandonment biochemical pedogenesis, or soil growth, in the upper portions of the mound extends into the upper regions of the concurrently developing B horizon. OCR_{DATES} obtained from the B horizon reflect the maximum depth of biochemical degradation as defined by the concurrent boundary formations exhibited by incipient argillic and stone line formation. Pedogenic formation of B horizons limit oxygen permeation, due to the combined effects of small pore space and decreased drainage rates, and effectively sets a lower limit of aerobic biodegradation.

The age of organic carbon within nonpedogenic mound fill is expected to be older than OCR_{DATES} obtained from the upper B horizon, and older than or contemporaneous with the age of the buried, original soil surface. The maximum age of fill soil will depend on depth and location of the borrow excavations. Thus, fill age likely predates buried pedogenic soil horizons, if mounds were constructed from subsurface and surface soils. The composite age of the pedogenically dead fill soils provides the basis for constructing hypotheses regarding mound construction techniques and fill soil excavation strategies.

An examination of soils from two mounds, Mound B from the Watsons Brake site in Louisiana, and Mound A from the Morse Mound Site in Texas demonstrate mound physiology and its implications for taphonomic assessments.

Watsons Brake Mound B

The Watsons Brake site is an 11-mound site complex located on the edge of an early Holocene channel of the Ouachita River in northeastern Louisiana. Recorded surface collections near and on the earthworks included Archaic projectile points, spherical cooking balls, and a small number of ceramics (Jones 1993). This assemblage led previous researchers to speculate that the site might date to the Late Archaic Period (ca. 4000 YBP), or to the Poverty Point Period ca. 3650-2150 calendrical YBP; 1950 (hereafter abbreviated YBP) (Saunders 1994).

Test excavations on earthworks conducted in 1994 recovered five sherds from the upper levels of Mound A and two ridges. However, found exclusively within and under the mound and ridges were projectile points, blades, microdrills, and fired earthen objects, artifact types that predate Poverty Point assemblages (>3500 YBP). Samples taken from within and below the earthworks of Mound B were recovered during the test excavations for radiocarbon (^{14}C), optically stimulated luminescence (OSL), and OCR analyses. Results indicate that construction of the earthworks occurred during the Middle Archaic Period, between 5400 and 5000 YBP (Saunders et al. 1997).

OCR Data (Table 1) reveal clues regarding some of the physiological processes of Mound B. The upper two samples (10 and 15 cm) demonstrate loading with coarse material and bases, at least relative to vertically adjacent samples. These upper two samples also show effects of accelerated weathering as evidenced by increases in fine particles.

The OCR_{DATE} for this event is 2658 ±80 YBP. The depth and date correspond with the broadly defined Poverty Point Period (ca. 3650-2150 YBP). The effects of base loading, weathered clays, and coarse particles can be seen through the profile down to 55 cm for the higher pH, down to 45 cm for increased fine particles, and down to 20 cm for coarse particles. The percent organic carbon and the OCR_{RATIO}, however demonstrate decreasing percent organic carbon and increasing OCR_{RATIO} with depth; these changes suggest normal pedogenic behavior from the surface down to 35 to 40 cm – with the possibility that the upper two levels reflect a turbation on and within the upper surface of a preexisting pedogenically active soil. The rate (depth/time) of illuviation of bases (pH) and both coarse and fine particles is greater than the illuviation of organic carbon.

Coarse particles increase below 20 cm reaching a second peak at 40 cm, and fine particles follow a similar increase between 45 and 50 cm. Taken in concert, the peaks in fine particles, coarse particles, organic carbon and the OCR_{RATIO} indicate a maximum depth of pedogenic carbon degradation at between 35 and 40 cm. Below these depths (40 cm coarse particles, 55 cm fine particles, and 40 cm organic carbon and OCR_{RATIO}), the aforementioned patterns in Table 1 are replaced by seemingly random changes, suggestive of fill material from varying locations and/or depths, exhibiting lack of evident coproduction processes normal to autopoietic systems. The OCR_{DATE} estimate at 40 cm is 5936 ±178 YBP. From 40 cm down to the buried sub-mound surface at 245 cm, age estimates range between 6290 and 5321 YBP. As a number of these fill samples date more recently than those at 40 cm, we concluded that organic carbon in the 40 cm sample is strongly influenced by residual characteristics, inherited from its previous location, not altered by recent in situ pedogenesis. As the OCR_{DATE} at 35 cm is later than all subsequent samples of fill material down to buried submound soils, we deduce that recent in situ pedogenesis has altered organic carbon in this sample. Thus, Mound B appears to have undergone pedogenesis since sometime before 5236 ±157 YBP. Cultural material recovered from between 20 cm and 45 cm would be

***Table 1**. Data from Mound B, Watsons Brake. Shaded entries reflect related data sets discussed in text.*

Soil depth	pH	%Organic carbon (LOI)	OCR date	Very coarse	Coarse	Medium	Fine	Very fine	Coarse silt	Fine silt	Sample Id	%Oxidizable carbon (WB)	OCR ratio
10	4.5	1.391	1554	2.963	.921	4.697	13.755	40.773	10.408	26.483	1575	0.56	2.48
15	**4.3**	**0.837**	**2658**	**5.005**	**.971**	4.308	13.531	40.666	10.475	25.044	1574	0.3	2.79
20	4.3	0.79	3959	1.571	.819	**4.320**	**13.754**	**39.823**	**12.147**	**27.566**	1573	0.26	3.04
25	4.3	0.643	4313	.819	.840	4.567	14.191	41.637	11.499	26.447	1572	0.16	4.02
30	4.3	0.521	4700	1.098	.716	4.443	14.490	45.843	10.265	23.146	1571	0.13	4.01
35	**4.2**	**0.454**	**5236**	1.940	.854	4.586	14.516	44.842	11.189	22.072	1570	0.09	5.04
40	4.3	0.367	5936	**4.752**	.904	3.728	13.575	47.871	11.399	17.772	1569	0.06	6.12
45	4.2	0.37	5855	1.172	**1.064**	**4.172**	**15.080**	**49.991**	10.887	17.634	1568	0.07	5.29
50	4.2	0.784	5889	.204	.917	4.020	14.012	49.033	**13.321**	**18.494**	1567	0.1	7.84
55	3.9	0.829	5706	.897	1.108	4.987	15.934	46.479	14.483	16.112	1566	0.14	5.92
60	3.9	0.792	5685	2.860	1.375	6.170	19.369	37.739	15.385	17.101	1565	0.14	5.66
65	4.2	0.893	5658	3.192	2.755	11.762	33.732	32.886	9.290	6.383	1564	0.13	6.87
70	4.1	0.532	5577	6.785	2.481	12.083	31.237	31.695	9.9655	5.754	1563	0.12	4.43
75	4.2	0.399	5765	3.840	3.238	14.331	28.322	35.667	7.745	6.857	1562	0.07	5.70
80	4.4	0.495	5780	2.858	1.618	8.675	22.917	42.219	14.752	6.961	1561	0.08	6.19
85	4.5	1.109	6282	.5424	.528	3.736	16.549	53.909	14.025	10.710	1560	0.07	15.84
90	4.4	1.009	6290	.	.284	1.681	13.222	54.595	16.521	13.698	1559	0.07	14.41
95	4.3	1.117	5736	.310	.312	2.149	13.648	54.036	18.465	11.082	1558	0.15	7.45
100	4.2	1.395	5567	.724	.700	2.792	13.527	46.670	17.107	18.480	1557	0.25	5.58
105	4.1	1.628	5568	.533	.530	1.685	9.708	49.811	17.935	19.798	1556	0.28	5.81
110	4.3	1.388	5458	4.031	.485	1.627	9.431	50.312	15.900	18.215	1555	0.34	4.08
115	4.5	1.633	5524	1.079	.405	1.574	7.349	45.779	20.751	23.064	1554	0.31	5.27
120	4.6	0.954	5502	.738	.522	1.840	7.596	51.804	15.435	22.066	1553	0.25	3.82
125	4.3	1.51	5537	2.144	.606	1.452	6.814	48.922	16.366	23.696	1552	0.29	5.21
130	4.4	1.709	5479	.751	.603	1.656	6.454	42.732	16.268	31.537	1551	0.39	4.38
135	4.5	1.693	5460	1.166	.516	1.334	6.092	40.229	13.994	36.669	1550	0.42	4.03
140	4.6	1.91	5439	.573	.572	1.239	5.384	39.512	12.593	40.126	1549	0.495	3.86
145	4.7	2.021	5402	.890	.425	1.526	5.523	37.133	13.933	40.571	1548	0.59	3.43
150	4.7	2.413	5468	4.021	.316	1.228	5.621	39.446	12.445	36.924	1547	0.46	5.25
155	4.7	1.819	5479	.332	.327	1.638	6.900	44.158	15.290	31.357	1546	0.39	4.66
160	4.8	0.919	5643	.672	.172	2.117	10.212	54.369	14.388	18.070	1545	0.16	5.74
165	4.9	0.753	5590	.296	.215	2.364	10.766	56.861	13.767	15.731	1544	0.16	4.71
170	5	0.624	5736	.235	.241	3.111	14.383	60.596	10.887	10.547	1543	0.1	6.24
175	5	1.06	5441	1.404	.424	2.783	11.548	56.884	12.348	14.609	1542	0.29	3.66
180	5.1	1.132	5414	.841	.366	2.137	10.823	56.777	13.222	15.834	1541	0.34	3.33
185	5.2	1.459	5359	3.857	.390	1.746	6.914	50.501	13.378	23.215	1540	0.52	2.81
190	5.3	1.708	5377	1.010	.356	1.462	7.872	52.017	14.065	23.218	1539	0.52	3.28
195	5.4	1.737	5364	2.683	.319	2.224	7.170	48.935	14.441	24.228	1538	0.55	3.16
200	5.6	1.827	5362	.848	.544	2.280	7.988	53.305	13.207	21.829	1537	0.56	3.26
205	5.9	1.618	5349	2.246	1.980	3.485	12.634	51.816	12.086	15.754	1536	0.51	3.17
210	5.9	1.562	5351	4.320	2.177	4.164	11.253	52.376	13.153	12.560	1535	0.48	3.25
215	5.9	1.519	5358	1.942	1.912	4.076	10.772	52.815	14.804	13.680	1534	0.47	3.23
220	5.9	1.439	5332	7.490	1.615	3.558	11.232	53.448	11.507	11.151	1533	0.49	2.94
225	5.9	1.956	5325	2.808	1.943	4.024	9.552	53.015	17.092	11.565	1532	0.65	3.01
230	6	1.52	5321	1.614	1.357	3.663	10.347	51.980	14.473	16.566	1531	0.61	2.49
235	6.3	1.796	5363	1.947	1.877	3.205	9.820	50.391	14.222	18.539	1530	0.49	3.67
240	6.4	1.649	5364	.4188	1.273	3.359	11.113	56.362	14.213	13.263	1529	0.465	3.55
245	**7**	**2.021**	**5284**	2.197	2.444	7.448	17.161	38.354	10.651	21.746	1528	0.85	2.38
250	7	2.421	5723	**6.509**	2.125	7.641	14.203	37.207	10.194	22.121	1527	0.76	3.19

contemporaneous with or immediately after mound construction.

Buried submound soils at a depth of 245 cm were pedogenically active soils, later suffocated (deprived of access to atmospheric oxygen) by overburden. Thus, buried soils record a time prior to mound construction. The $\mathrm{OCR}_{\mathrm{DATE}}$ obtained from the upper sample of the buried surface under the mound at Watsons Brake is 5284 ±159 YBP. Thus, Mound B at Watsons Brake was constructed sometime between $\mathrm{OCR}_{\mathrm{DATES}}$ of 5284 ±159 and 5236 ±157 YBP. Cultural material recovered from below 45 cm within the mound fill and buried sub-mound soil may predate or be contemporaneous with Mound B construction.

Morse Mounds – Texas

The Morse Mounds site contains two earthen mounds and covers between 4 and 5 acres of a ridge crest and slope between two tributaries of Chicken Bayou, a perennial stream in the Flat Fork Creek drainage basin of east Texas (Perttula 1989:75). The literature lacks radiocarbon dates and detailed discussions of material culture from Mounds A and B, or the Village area. However, information in

Bruseth et al. (2000), along with personal communications with Tom Middlebrook, who is preparing the report of findings, indicates that Mounds A, B, and the Village area are probably contemporaneous, and date to the Late Caddoan period (Frink and Pertulla in press).

Mound A was built over a 5.6-m diameter circular Caddoan structure (Structure 1) built atop the natural ground surface. A burial pit was then excavated inside and through the structure, extending ca. 1.25 m below the ground surface (Bruseth et al. 2000:5). At that point, the structure was burned, and structural remains and sandy clay fill were dumped into the burial pit depression and over the structure, creating the mound itself. At the time the mound was constructed, "the depression was present" (Bruseth et al. 2000:5).

The OCR column at Mound A is from the north wall of block excavations, just outside of Structure 1 (see Bruseth et al. 2000: Fig. 2). The soil profile documents five zones from 0-118 cm below surface (bs). Zones I, II, and III, extending from 0-82 cm bs, represent mound fill. Zones IV and V, from 82-118 cm+ bs, are the top of the natural ground surface, but now buried under the mound:

Zone I, 0-9 cm, dark brown loam with charcoal and clay mottles

Zone II, 9-53 cm, yellowish-brown sandy clay with ferro-manganese concretions, clay mottles, and charcoal chunks

Zone III, 53-82 cm, yellow sandy clay with red and gray clay mottles and ferro-manganese concretions

Zone IV, 82-110 cm, strong brown sandy loam with light brown mottles and a few ferro-manganese concretions, buried A-horizon and the surface of Structure 1

Zone V, 110-118 cm+, light yellowish-brown sandy loam with few ferro-manganese concretions

OCR samples were taken at 5-cm intervals, beginning at 10 cm bs and extending to 115 cm bs, resulting in a total of 22 OCR samples were obtained from Mound A, including nine in Zone II, six in Zone III, six in Zone IV, and one in Zone V. No OCR samples were taken from Zone I, as it appeared to have been disturbed by modern farming activities. The inverse pH values in the surface pedon (10 to 40 cm bs) indicate recent carbonate loading to these soils, likely from agricultural liming of the field. In addition, the high percent organic carbon values in the upper 20 cm, along with the lack of associated significant coarse and fine particle accumulations within the pedogenically active zone suggest recent agricultural activities.

Table 2 shows the soil profile from Mound A at 41SY27 along with the soil data obtained from the OCR analyses. Like Mound B at Watsons Brake discussed above, Mound A is a simple mound with only one building event separating two periods of pedogenic stability, namely the current surface and the buried premound surface (paleosol). Highlighted data for soil texture at 25 cm in Table 2 shows incipient stone line (coarse particles) and argillic horizon (fine particles) at 45 cm as they have evolved downward through the mound fill since mound construction. The trending $\text{OCR}_{\text{RATIO}}$ increases until it peaks between 20 and 25 cm. The maximum depth of pedogenic organic carbon in the upper pedon (478 ±14 YBP). Note the random and

***Table 2**. Data from Mound A, Morse Mounds. Shaded entries indicate data emphasized in text.*

Soil depth	pH	%Organic carbon (LOI)	OCR date	Very coarse	Coarse	Medium	Fine	Very fine	Coarse silt	Fine silt	Sample Id	%Oxidizable carbon (WB)	OCR ratio
10	4.9	3.043	163	3.519	2.589	.360	1.366	24.475	23.999	43.692	4357	0.66	4.61
15	4.8	2.709	358	2.608	3.030	.808	2.273	26.695	29.236	35.350	4358	0.53	5.11
20	4.8	2.713	459	3.012	3.354	1.025	2.080	24.062	30.045	36.422	4359	0.38	7.14
25	**4.7**	**2.27**	**478**	**3.404**	1.664	.815	1.605	29.180	25.418	37.913	4360	0.33	6.88
30	4.3	2.084	484	2.581	**2.753**	.926	1.842	24.319	29.379	38.201	4361	0.33	6.32
35	4.2	1.674	444	4.287	1.935	**1.080**	**1.808**	**24.406**	27.347	39.137	4362	0.33	5.07
40	3.7	1.46	506	6.264	.896	.387	1.296	22.638	**28.561**	39.959	4363	0.28	5.21
45	3.7	1.255	669	6.991	.815	.457	1.243	23.167	26.913	**40.414**	4364	0.18	6.97
50	3.8	1.46	689	7.937	1.155	.313	1.501	23.594	29.046	36.454	4365	0.18	8.11
55	3.8	1.269	836	3.928	.781	.257	1.379	25.670	34.471	33.515	4366	0.14	9.06
60	3.7	1.162	740	4.614	.724	.365	1.438	27.182	40.994	24.685	4367	0.15	7.75
65	3.8	1.218	801	4.381	.748	.220	1.325	26.584	39.495	27.247	4368	0.14	8.70
70	3.8	1.222	799	3.159	.695	.271	1.300	28.047	45.396	21.133	4369	0.14	8.73
75	3.8	1.249	789	2.265	.630	.166	1.397	25.245	44.898	25.399	4370	0.15	8.33
80	3.7	1.209	720	3.045	.590	.217	1.376	31.957	41.116	21.699	4371	0.16	7.56
85	3.7	1.039	841	1.666	.587	.321	1.498	29.821	24.993	41.113	4372	0.135	7.70
90	3.8	0.969	914	4.738	.521	.234	1.330	28.029	27.843	37.305	4373	0.11	8.81
95	3.8	0.875	981	2.972	.911	.279	1.450	25.104	30.252	39.033	4374	0.1	8.75
100	**3.9**	**0.71**	**775**	1.777	.998	.301	1.438	26.005	29.532	39.951	4375	0.12	5.92
105	3.9	0.856	782	1.959	.860	.265	1.374	26.386	28.544	40.612	4376	0.13	6.58
110	3.9	0.969	951	2.517	.862	.281	1.259	24.589	29.236	41.255	4377	0.11	8.81
115	4	1.151	1016	2.711	.804	.375	1.268	23.732	28.937	42.174	4378	0.11	10.4

Table 3. *Data from Rmiz, Czech Republic. Shaded entries indicate data emphasized in text.*

Soil depth	pH	%Organic carbon (LOI)	OCR date	Very coarse	Coarse	Medium	Fine	Very fine	Coarse silt	Fine silt and clay	Sample Id	%Oxidizable carbon WB	OCR ratio
5	**3.4**	**8.241**	**434**	8.173	2.340	1.991	2.729	1.997	7.093	75.678	4185	3.15	2.62
10	3.1	4.188	1710	**10.401**	**2.550**	**1.735**	**1.347**	**1.300**	**5.369**	**77.299**	4186	1.26	3.32
15	**3.1**	**3.578**	**2279**	23.245	3.841	1.716	1.275	1.345	4.454	64.123	4187	1.03	3.47
20	3.1	2.353	2677	**40.829**	4.460	1.615	1.090	.981	3.82	47.202	4188	1.13	2.08
25	3.1	1.912	2982	**60.360**	**4.343**	1.261	.764	.623	2.474	30.176	4189	0.98	1.95
30	3.1	1.601	3437	45.298	7.000	**1.968**	**1.096**	**.926**	**2.719**	**40.991**	4190	0.76	2.11
35	3.2	1.522	3514	45.603	7.909	2.686	1.597	1.116	3.050	38.039	4191	0.56	2.72
40	3.8	1.727	4148	37.274	4.327	2.223	2.055	2.073	4.603	47.446	4192	0.59	2.93
45	**3.9**	**1.809**	**4272**	23.975	6.756	5.138	2.362	3.390	5.053	53.326	4193	0.53	3.41
50	**4.1**	**2.313**	**4604**	**28.154**	5.074	3.152	1.593	3.607	5.631	52.789	4194	0.78	2.97
55	4.2	2.144	4731	19.939	**8.018**	**8.111**	**3.503**	**3.898**	**4.782**	**51.749**	4195	0.55	3.90
60	**4.6**	**1.819**	**5163**	**41.572**	5.843	4.525	4.026	2.558	3.890	37.587	4196	0.71	2.56
65	4.8	1.835	5303	25.376	**6.702**	5.701	2.737	3.849	4.654	50.980	4197	0.43	4.27
70	4.8	1.933	5505	14.3012	6.918	**8.486**	**4.687**	**4.998**	6.126	54.484	4198	0.37	5.22
75	**4.9**	**2.107**	**5622**	18.324	2.456	2.162	1.574	2.841	**6.543**	**66.101**	4199	0.64	3.29
80	4.9	1.836	5820	**32.398**	**4.345**	**1.690**	**3.153**	**2.689**	**5.115**	**50.611**	4200	0.315	5.83

OCR_{DATE} at this depth (25 cm) represents the unordered sequence of organic carbon, pH, and OCR_{DATE} values below this level (25 to 95 cm bs) representing the unmodified (nonpedogenic) mound fill. Data in Table 2 from 25 to 95 cm, therefore, represent pedogenically-derived characteristics inherited from the fill soil's original position within a pedogenically active profile.

Buried submound soils occur below 95 cm. Data for these formerly pedogenically active soils demonstrate normal ordering for pH, coarse particles, OCR_{RATIO} and OCR_{DATE} increasing with depth. The age of the organic carbon at the surface of this buried horizon is 775 ±23 YBP. This buried surface does not show a definable stone line or argillic horizon in Table 3, but both would be expected below the excavation, as data reveal increasing values for both coarse and fine particles, as well as for pH and OCR_{RATIO} values down to the extent of sampling.

Ramparts

Ramparts are essentially linear mounds, and may be characterized by multiple episodes of rebuilding, vertically, horizontally, or a combination of both. Ramparts are often accompanied on the landscape by a ditch, the source of most, if not all, of the construction material. A pallisade of wooden posts may cap the rampart, and or breastworks of stone may provide a face. Ramparts may function as defensive structures, keeping people and or wild animals out of the enclosed space (Fowke 1902), or as boundaries defining sacred space (Griffin 1952), or secular space (Drewett 1977).

Rmiz is a 17.5-hectare Late Neolithic/Copper Age enclosed hill-top site, located in the Moravian Valley, Czech Republic. Late Neolithic/Copper Age in Moravia is characterized by pottery from the Funnel Beaker culture (TRB). This site is one of 11 (or more) enclosed villages/forts located between Olomouc in the north to Brno in the south. The enclosure of Rmiz is situated on a steep sloped promontory overlooking Hana Valley, the western most section of the Moravian Valley. This section focuses on the Enclosure 3 Rampart Wall (TU 2/99) at Rmiz.

Two stone walls with earthen fill between comprise the central rampart of Enclosure 3, within which may also exist a wooden pallisade (Smid 1993). The level of complexity exhibited in this rampart is unique to the overall Rmiz site, raising questions about the temporal relationship of construction sequences. The main question is whether both walls were constructed at the same time, or whether one wall represents later enhancement of the original rampart.

Excavation unit TU 2/99 exposed upper surfaces of both walls and soil/fill material immediately behind each. Coarse particle fabric, or the orientation of stones from the collapsed and intact walls, indicates that the inner wall may have post-dated the outer wall.

Excavations continued into the soils/sediments behind the inner wall to test this hypothesized relationship. Late Medieval Period (roughly 450 to 650 YBP for this part of Europe) ceramics were recovered in the upper 10 cm. Late Neolithic/Copper Age artifacts were recovered exclusively below these surface soils primarily from 40 to 62 cm (Frink et al. in prep.). Two post molds, suggesting the presence of a second pallisade, were discovered to the inside of the inner wall, adding to the complexity of this monumental earthwork.

Five independent pedogenic events (defined here as individual pedons) are evident in samples from the soil profile (Table 3). At the surface, 0 to 7 cm, Pedon 1 represents the upper portion of a pedogenic E horizon developed within relatively recent colluvial slope wash, and welded onto an earlier surface (Pedon 2). Loading of bases and organic carbon, as well as an increase in fine particles in the upper 10 cm of the profile distinguishes Pedon 1 from Pedon 2. The OCR_{DATE} for Pedon 1 is 434 ±13 YBP. This date is consistent with the Late Medieval Period ceramics recovered from the upper 10 cm of the excavation unit.

The second pedon extends from 8 to 39 cm, and consists of the lower portion of the current pedogenic E horizon and Bw horizon, formed in earlier slope wash deposits. Based on the developing stone line (20 to 25 cm), incipient argillic horizon (30 cm), and $\text{OCR}_{\text{RATIO}}$ (15 cm) Pedon 2 grew pedogenically during the past ca. 2280 years. Characteristics of the samples from 20 to 35 cm, specifically $\text{OCR}_{\text{RATIO}}$, pH, and the OCR_{DATE}, suggest that sediments composing Pedon 2 aggraded over a period of nearly 2000 years, prior to stabilizing.

Pedon 3, extending from 40 to 52 cm, represents the upper portion of an aggraded paleosol – a buried A horizon. This pedogenically stable soil developed in sediments associated with human habitation. A discontinuity in pH values compared to soils above, an increase in organic carbon, and a decrease in coarse particles with a concurrent increase in cultural material all suggest that Pedon 3 represents a cultural surface sheet midden. The youngest OCR_{DATE} of this pedon (45 cm – 4272 ±128 YBP) provides an age estimate for abandonment of this portion of the site, while the oldest age of this pedon (50 cm – 4604 ±138 YBP) probably reflects the beginning cultural land use represented for Pedon 3.

Pedon 4 includes the lower portion of the same paleosol, but is contemporaneous with construction of the inner stone wall and the second palisade. Pedogenic alteration of these sediments are limited, but some pedogenesis is still evident in values for pH, fine particles, and $\text{OCR}_{\text{RATIO}}$. The age of soil disturbance associated with construction of the inner stone wall and palisades is indicated by $\text{OCR}_{\text{DATES}}$ for 65 and 70 cm levels of 5303 ±159 and 5505 ±165 YBP, respectively. The OCR_{DATE} at the 60 cm level (5163 ±155 YBP) suggests a period of roughly 150 years transpired prior to change in cultural land use patterns and buildup of midden deposits above 60 cm. Additional samples from each of the two post molds returned $\text{OCR}_{\text{DATES}}$ of 5582 ±167 YBP and 5536 ±166 YBP.

Pedon 5 represents a buried surface under backfill sediments (Pedon 4) associated with the construction of the inner stone wall. As such, the latest age of Pedon 5 (75 cm – 5622 ±169 YBP) would approximate, but predate somewhat the construction of the inner stone wall. The 75-cm sample is from a thin (2 cm), poorly developed A-horizon (3Ab) overlying an unweathered C-horizon (3C). Because of limited pedogenic development in Pedon 5, it is likely that these soils developed in sediments disturbed during an early phase of wall construction (i.e., construction of the outer stone wall and palisade). Construction of the outer stone wall and rampart is, therefore, younger than the OCR_{DATE} for the 80 cm sample (5820 ±175 YBP).

Geoglyphs and Rock Coatings as Examples of Monumental Earthworks

Jay von Werlhof devoted much of his professional life to the study of geoglyphs in southwestern North America. A true pioneer, von Werlhof teamed with pilot Harry Casey to document and study these earthen figures largely ignored by academics choosing to pursue topics more respected by their subdisciplinary paradigms (cf. Fuller 2000).

Acceptance and integration of geoglyphs as monumental earthworks must be based on common epistemological and analytic procedures. The following case studies using the OCR procedure represent one step toward this end. Our goal, at this point, is not to obtain correct numerical $\text{OCR}_{\text{DATES}}$. As will become evident in the following discussion, additional research of desert soils, rock coatings, and the physiological affects resulting from human and natural turbations are needed to contexturalize and define resulting patterns. Rather, our objective here is to test whether the OCR procedure can be used to discriminate relative ages between human altered and unaltered soil and soil like systems, and thereby its potential use in characterization of these systems' physiological processes. Thus, the reader should not interpret the calculated "OCR_{DATE}" as anything other than a relative age assignment guided by equation coefficients that will need refinement through future blind testing.

Because our objectives are preliminary, different, though similar analytic procedures have been substituted into the OCR analysis. Specifically, the procedure used to determine percent organic carbon, textural determinations, and the scale consideration in measuring depth. Total percent organic carbon is determined using the procedure described by Dean (1974), where samples are ignited at higher temperatures for shorter periods of time. Ignition at higher temperatures may result in variations due to weight loss of structural water from clay minerals (Ball 1964). While similar results are anticipated from these two procedures, we did not cross-calibrate these methods for different types of samples.

Textures are determined by a combination of sieves and hydrometer methods. Gravel to medium sand textures are determined by sieving, and sand, silt, and clay fractions are determined by the hydrometer method.

Soils occupy space at a scale measurable at the centimeter level, while rock coatings and some weathering rinds occupy space that would be more appropriately measured in millimeters or microns. No attempt has been made to recognize these different scales, and the potential accuracy such recognition would afford the OCR_{DATE} calculations. Furthermore, no attempt has been made to describe physiological patterns definable by depth for these studies.

Av-Horizons within Ripley Geoglyphs, Arizona

Figure 1 illustrates a group of geoglyphs on a terrace of the Colorado River in western Arizona. Figure 2 shows a ground view of two of these geoglyphs: an anthropomorph and a cross. The removal of gravel desert pavements expose lighter-colored silt underneath (Figueira and Stoops 1983). Removal of the pavement is a major turbation that affects the trajectory of pedogenesis that should be evident in the chemistry of the Av horizon. Vesicular A horizons (Av) are common in desert soils with high eolian silt and clay content. Millimeter-scale spherical vesicles (giving the Av designation) in the A horizon may form when soil air expands as temperatures quickly increase in the summer after rainfall. Our goal is to explore whether and how organic matter in the silty Av horizon might have been changed by the anthropogenic turbation.

Five samples of Av soil horizon from 2-5 cm within the geoglyphs were collected with assistance from and permit to Jay von Werlhof and Harry Casey. In addition, seven subsamples were collected from 7-10 cm under the adjacent natural pavement surface. These soil samples were then subjected to analyses required for the OCR procedure (Table 4).

The formation of Av horizons places constraints on interpretation of OCR_{DATES}. If vesicular horizons represent reworking of materials by wind (Walther 1891), water (Sharon 1962, Wainwright et al. 1999), or internal sorting mechanisms (Springer 1958), then OCR_{DATES} could represent the true age of the soil. If Av horizons, however, represent addition of eolian dust (Jessup 1960, Mabbutt 1979, McFadden et al. 1998, Shepard et al. 1995) – essentially floating pavement cobbles on top of the growing vesicular horizon – then OCR_{DATES} would represent the ongoing mixing of younger organics and organic carbon that had undergone more extensive diagenesis.

It is not possible to rule out any of the pavement-forming processes at the Ripley site, except dominant wind deflation. Deflation is an unlikely explanation for lag formation, since eolian action would have removed the abundant fines (Table 4) and would have abraded rock varnish coatings. We cannot falsify, however, overland flow, upthrust of cobbles, or deposition of desert dust as mechanisms to form the natural pavement and regenerated pavement reformation inside the geoglyphs.

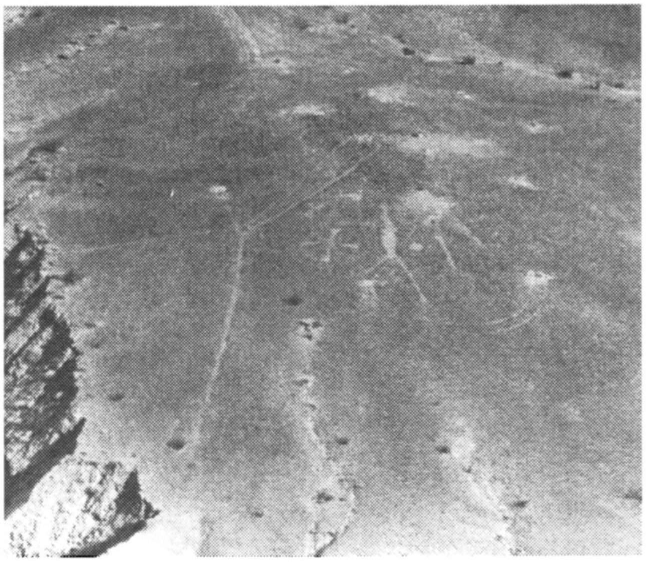

Figure 1*. Ripley geoglyph site on the eastern terrace of the Colorado River, far western Arizona, across, named for proximity to Ripley. The precise location is not provided to discourage visitation and preserve geoglyph integrity.* Larrea tridentata *(creosote) bushes, approximately a meter in diameter, provide scale.*

Figure 2. *Ground view of anthropomorph and cross geoglyph at the Ripley geoglyph site, Arizona.*

The consistently younger OCR signal in the cross and anthropomorph geoglyphs indicates that these geoglyphs are younger than the natural pavement context into which they were formed (Table 4). While differences in calculated age may be explained in part by the absence of the desert pavement in the calculation of depth for the samples from the glyphs – data with and without pavement – the OCR_{RATIO} demonstrates an inherent difference beyond the presence, absence, or degree of maturity of pavement.

At first glance, however, our uncalibrated $\mathrm{OCR}_{\mathrm{DATES}}$ under the natural desert pavement appear far younger than the age of the terrace cobbles. The natural pavement is well developed, and the underlying soil exhibits at least stage 3 pedogenic carbonate development (cf. Machette 1985). However, confirmation of the feasibility of these $\mathrm{OCR}_{\mathrm{DATES}}$ comes from Steve Forman, who obtained Holocene thermoluminescence ages on Av horizon material under much older Pleistocene pavements (McFadden et al. 1998). Because the $\mathrm{OCR}_{\mathrm{DATES}}$, ranging from ~4600 to ~5200 for Av horizon material under natural pavement, are consistent with the eolian flotation hypothesis for pavement genesis (Jessup 1960, Mabbutt 1979), our tentative mental model is to think of these $\mathrm{OCR}_{\mathrm{DATE}}$ as some average of the ongoing addition of organic carbon to the soil – combined in a linear, or non-linear, fashion with organic carbon experiencing ongoing pedogenic diagenesis.

Similarly, consistently younger OCR signals in the cross and anthropomorph indicate that these geoglyphs are likely older than ages presented in Table cumulic system may be analogous to mean residence time (MRT) radiocarbon ages for soil A horizons, 4. In other words, the $\mathrm{OCR}_{\mathrm{DATES}}$ in this open, or indicate a freshening of these constructs by later people. We stress that a method of determining minimum-limiting ages for geoglyphs would be a tremendous advance in Arizona and elsewhere in the southwestern USA. Thus, we are heartened by the correct relative ordering of natural pavement yielding significantly older $\mathrm{OCR}_{\mathrm{DATES}}$ than geoglyphs (Fig. 3).

The next steps in testing this experimental method of dating geoglyphs would be modeling relationships between $\mathrm{OCR}_{\mathrm{DATES}}$ and the true timing of geoglyph manufacturing. Unfortunately, this is the case of the blind leading the blind, for geoglyph ages are unknown. Still, we propose two approaches. First, we welcome blind comparisons of $\mathrm{OCR}_{\mathrm{DATES}}$ against MRT ^{14}C dating of organic carbon in geoglyph Av horizons. Second, we welcome blind comparisons of $\mathrm{OCR}_{\mathrm{DATES}}$ against luminescence dating approaches to splits of the same Av-horizon sample.

CASE STUDIES OF TAPHONOMIC EXPLANATIONS AT ROCK WEATHERING SCALES

Rock Weathering Rinds as Analogous to Residual Soils

Geoglyphs are extraordinarily difficult to date. In the case of the Nasca lines, for example, associated archaeological pottery remains have been key in developing a preliminary chronology (Clarkson 1990, 1994; Silverman 1990). Since no pottery, or other cultural material, has yet been recovered from the Ripley site, we turn to nearby grinding slicks or

***Table 4.** Data from Ripley Geoglyph Site, Colorado River Terrace, western Arizona. The site has a historical mean annual temperature of approximately 19.4° C and a mean historical annual precipitation of 17 cm. Textures are by percent weight. Ages reported in calendar YBP -- 1950 (cf. Frink 1992, 1994). Shaded entries indicate data emphasized in text.*

Sample Id	OCR (Age)	Percent organic carbon (LOI)	Percent oxidizable carbon (WB)	OCR ratio	Gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	pH
Natural Pavement 1	5114	0.10	0.0037	27.0	9	8	0	5	20	39	19	8.1
Natural Pavement 2	5170	0.12	0.0038	31.6	12	2	5	6	18	52	5	8.2
Natural Pavement 3	4217	0.13	0.0051	25.5	9	4	3	7	19	44	13	8.2
Natural Pavement 4	5677	0.09	0.0027	33.3	8	16	4	15	12	32	14	8.4
Natural Pavement 5	4241	0.14	0.0048	29.2	16	7	3	12	9	38	15	7.8
Natural Pavement 6	4453	0.15	0.0047	31.9	20	5	3	0	19	37	16	8.0
Natural Pavement 7	4633	0.12	0.0047	25.5	9	0	4	2	25	43	17	8.1
Anthropomorph 1	792	0.29	0.0151	19.2	0	12	7	12	20	37	11	8.5
Anthropomorph 2	1108	0.22	0.0112	19.6	3	5	2	7	17	50	15	7.9
Anthropomorph 3	811	0.42	0.0197	21.3	8	3	5	3	14	45	22	8.3
Anthropomorph 4	477	0.35	0.0228	15.4	11	12	8	15	15	27	13	8.6
Anthropomorph 5	563	0.33	0.0231	14.3	15	3	5	0	19	30	27	8.1
Cross 1	851	0.21	0.0122	17.2	4	6	13	17	9	36	15	7.8
Cross 2	423	0.37	0.0278	13.3	0	9	17	20	16	29	9	8.6
Cross 3	661	0.22	0.0136	16.2	3	11	21	12	22	23	8	8.4
Cross 4	572	0.19	0.0135	14.1	5	18	22	16	11	21	7	8.2
Cross 5	728	0.22	0.0132	16.7	0	5	26	22	8	28	11	8.2

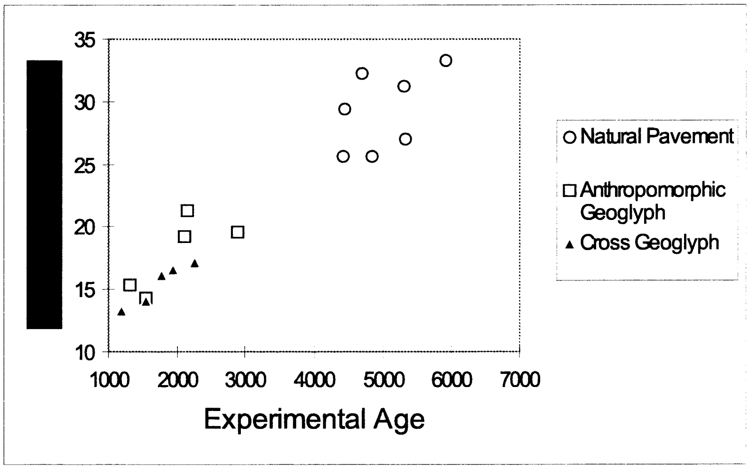

Figure 3. *Comparison of Organic Carbon Ratio and experimental OCR ages of samples at the Ripley geoglyph site. The experimental ages should only be viewed from the perspective of relative age, since the coefficients used to calculate the ages have not been tested for the Colorado River region.*

metates. The act of grinding down the natural basalt surface disturbs rock weathering rinds. Our goal is to explore whether and how organic matter in rock weathering rinds might have been changed by this anthropogenic turbation.

Weathering rinds commonly form where rock material is exposed to water. For example, weathering rinds form around the margins of rocks in contact with soils, or along subsurface fractures in the rock where water flows. Weathering rinds are sometimes seen visually as buff-colored alterations a few millimeters to centimeters thick, but, more often than not, significant discolorations are not readily visible. Archaeologists often use catch-all terms such as patina or patination to mean any discoloration on or around the rim of a rock, instead of terms connoting the unique diagenetic process such as weathering rinds, rock coatings and other surficial alterations (Service 1941, Dorn 1998).

At sites a few hundred meters away from the Ripley geoglyph complex are lithic scatters and andesitic boulders containing grinding slicks or metate features. Metate weathering-rind samples were collected with Jay von Werlhof, as a part of the geoglyph project discussed above The three depression analyzed here had diameters and pit depths of 35 cm-6 cm for metate 1, 40 cm-8 cm for metate 2, and 45 cm-4 cm for metate 3. Three subsamples of the upper 2 cm of rock weathering rinds were collected from each of these metates. In other words, rock chips were taken from three separate places on each of the metates.

Natural rock depressions were also sampled for comparison with the metate samples. These natural depressions are sometimes called gnamma or more often weathering pits. The three weathering pits analyzed here had diameters and pit depths of 29 cm-7 cm for pit 1, 33 cm-4 cm for pit 2, and 55 cm-5 cm for pit 3. Again, three subsamples of the upper 2 cm were collected from each of these weathering pits.

Our focus rests on the nature of the organic carbon signal and whether natural weathering pits and anthropogenic metate surfaces differ in the OCR_{RATIO} signal. Thus, we measured the percent carbon (loss on ignition), percent carbon oxidizeable through the Walkley-Black procedure, and pH of the weathering rind material. Examination of the weathering rind in cross-section with back-scattered electron microscopy reveals a matrix of clay-sized particles hosting the organic matter. Lacking comparative data on oxygen diffusion rates through rock coating material as opposed to soils, we use the clay texture in our calculations with the understanding that this is an uncertain assumption. It is possible that a slower diffusion rate for oxygen, and thus an older resulting age, will be defined through future studies. Table 5 presents data necessary for OCR procedure of these samples.

Data in Table 5 reveal great intra-sample and inter-sample variability, with several potential implications. First, some internal variability may result from taking "bulk" samples across approximately 2 cm of weathering rind. Second, internal variability in ages appear to be heavily dependent on the percent organic carbon in the sample. In other words, those metate and weathering pits with the highest concentrations of organic carbon yield the youngest OCR_{DATES}. Third, the greater variability in the metate samples may have to do with

Table 5. *Data from Metate and Weathering Rind study, near Ripley geoglyph site, Arizona. The site has a historical mean annual temperature of approximately 19.4° C and a mean historical annual precipitation of approximately 17 cm. The depth of each sample came from the upper 2 cm. The clay matrix seen in electron microscopy is used for texture for the purpose of* OCR_{DATE} *calculations.* OCR_{DATES} *are reported in calendar YBP -- 1950 (cf. Frink 1992, 1994). Shaded entries indicate data emphasized in text.*

Sample	% C (LOI)	Percent oxidizeable carbon (WB)	OCR (Date)	OCR ratio	pH
Metate 1a	1.2	0.18	142	6.7	6.2
Metate 1b	0.75	0.090	246	8.3	6.5
Metate 1c	not measurable				
Metate 2a	0.15	0.010	1018	15.0	8.1
Metate 2b	not measurable				
Metate 2c	2.5	0.46	50	5.4	7.2
Metate 3a	0.22	0.020	708	11.0	5.9
Metate 3b	0.94	0.11	217	8.5	6.7
Metate 3c	0.66	0.060	360	11.0	6.7
Weathering Pit 1a	0.85	0.063	445	13.5	5.4
Weathering Pit 1b	0.26	0.021	813	12.4	4.9
Weathering Pit 1c	0.44	0.038	551	11.6	5.2
Weathering Pit 2a	0.18	0.010	1459	18.0	4.9
Weathering Pit 2b	0.12	0.0084	1221	14.3	6.5
Weathering Pit 2c	0.12	0.0059	1672	20.3	7.2
Weathering Pit 3a	0.94	0.053	501	17.7	6.8
Weathering Pit 3b	1.24	0.064	503	19.4	6.1

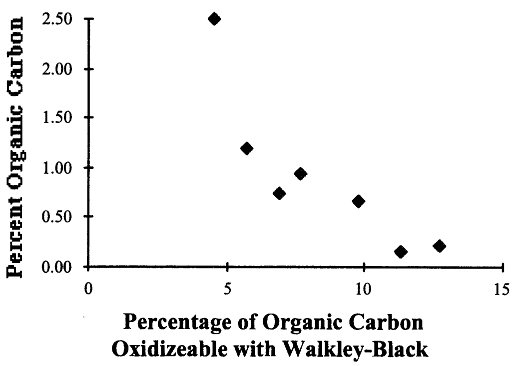

Figure 4. *Comparison of total organic carbon and the percentage of that organic carbon oxidizeable through the Walkley-Black procedure for metate samples from the Ripley site. A comparison of percent organic carbon versus age in Table 5 reveals that samples with younger OCR ages contain more total organic carbon.*

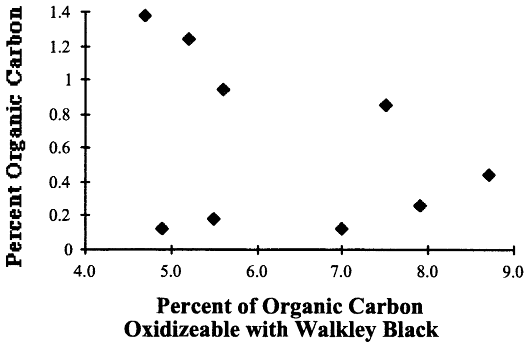

Figure 5. *For natural weathering pit samples, comparison of total organic carbon and the percentage of that organic carbon oxidizeable through the Walkley-Black procedure. At the lowest concentrations of organic carbon, there appears to be a clear age trend, where the lowest concentrations of organic carbon yield the oldest ages. However, at concentrations greater than 0.8%,* OCR_{RATIO} *and hence relative age relationships are unclear.*

anthropogenic inputs of organics – literally ground into weathering rind fractures. A fourth possibility would be varying degrees of diagenesis and subsequent loss of preexisting older carbon, for example inherited inertinite and vitrinite (cf. Chitale, 1986). Fifth, variability in pH influences ages, with potential causes related to different types and concentrations of surface organisms (e.g., lichen, algae, fungi lithobionts) as documented elsewhere (Krumbein and Dyer 1985, Krumbein 1988, Krumbin and Urzi 1993, Dorn 1998).

Readily apparent in metate samples (Fig. 4), but not in the natural weathering pit samples (Fig. 5), is a negative correlation between the amount of carbon in the weathering rind and the percent of that organic carbon oxidized through the Walkley-Black procedure. Samples with the least amount of total organic carbon have the oldest OCR_{DATES}. One explanation is the possibility that some of the metate's organic carbon came from organic matter anthropogenically ground into the rock's weathering rind pores, and this anthropogenically added carbon, being younger than the natural sources already incorporated into the rind, has a higher degree of susceptibility to the Walkley-Black procedure. Put another way, subsamples with low concentrations of organic carbon could possibly represent organic matter "inherited" from insertion during a prior episode of rock weathering (cf. Phillips 1963, Chitale 1986, Danin et al. 1987, Bruand et al. 1996, Jackson et al. 1997).

Our findings have significance for future attempts to date the carbon in metate samples. To the best of our knowledge, radiocarbon dating of metates from organics pounded into the weathering rind has not yet been tried in archaeological research; however, our results suggest that bulk samples of organic matter will be unlikely to yield accurate radiocarbon or $\text{OCR}_{\text{DATES}}$. However, the OCR procedure may serve as a way to inexpensively identify samples for more detailed characterization of the different types of organic matter, or as a prelude to future AMS ^{14}C dating of the different types of organic matter ground into metate samples. For example, OCR or stable carbon isotope analyses, or both, may be necessary first steps in deciding whether a sample represents "inherited" organics from the weathering rind, or organics pounded into the metate during its anthropogenic use.

Rock Varnishes as Analogous to Cumulic Soils

Rock varnishes form on natural and anthropogenic surfaces, including stones exposed through geoglyph manufacturing. Rock varnish and other rock coatings contain organic carbon (Dorn 1998). In the case of rock varnish, the organic carbon within the varnish itself yields radiocarbon ages ranging only from modern to a few hundred years old. The oldest intravarnish radiocarbon ages are a few thousand years old even when other chronometric indicators indicate the varnish should be much older (Dorn 1998, Dragovich 2000, Staley et al. unpubl. ms.). There are several reasons for these anomalously young radiocarbon ages: (a) organic carbon is in an open system; (b) many varnishes contain microcolonial fungi – which erodes pits into varnish – inserting younger fungal organic carbon upon decay; (c) the amount of organic carbon is greatest at the surface – where epilithic bacteria and fungi occur in greatest abundance (Dorn 1998). An additional problem in radiocarbon dating of rock varnish is the addition of older contaminants found in the underlying weathering rind material, discussed in Dorn (1997). Thus, radiocarbon dating of organic carbon within rock varnish remains problematic until these issues are resolved and controlled.

A potential chronometric approach rests in analyzing temporal trends in younger organics that are routinely mobilized within rock varnish layers. In other words, whereas the radiocarbon approach requires a closed system, the OCR approach treats varnish as a dynamic autopoietic system with metabolic exchanges. Thus, the goal of this section is to explore how organic carbon within rock varnishes might change as a function of depth within the varnish in an open system. Although our samples do not come from geoglyphs, they derive from natural varnishes immediately adjacent to geoglyphs.

Most of the published efforts to radiocarbon date the organic matter within rock varnish have not considered whether the varnish went through a series of building and then erosional episodes. For example, the unlayered varnishes in Figure 6 show the insertion of organic carbon into a "pit" eroded into the varnish. The pit could have been made by the secretion of acids 50,000 or 1000 years ago, and then filled in with organics. With layered varnishes, in contrast, the researcher has some degree of confidence that the deposit did not suffer a major erosional event – with the potential to insert an "infill" of newer carbon. Thus, existing radiocarbon ages for intra-varnish organic carbon is nothing more than a hodgepodge of poorly characterized samples – analogous to picking charcoal out of tree-fall pits and intact sedimentary sequences – and characterizing all of these samples as the same sort of deposit. This is why Dorn (1997) originally turned to the radiocarbon dating of organic matter underneath the varnish.

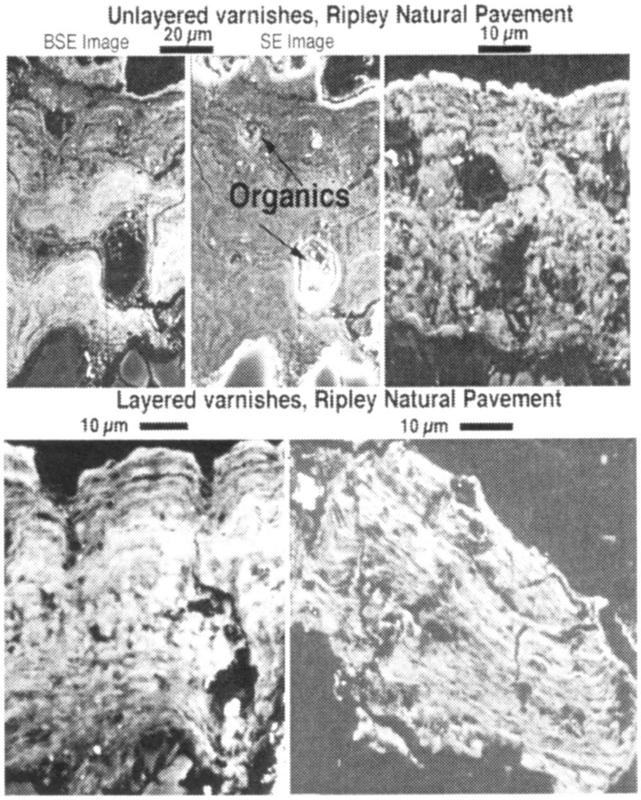

Figure 6. *Electron microscope imagery of layered and unlayered varnishes on natural pavements from the Ripley Geoglyph site, Arizona. All but one image was taken with back-scattered electron microscopy, where brightness records average atomic number. The upper row illustrates unlayered varnish structures, where organics trapped in pockets are revealed by secondary electrons (organics bright in secondary electrons and black in back-scattered electrons) and corresponding wavelength*

In an effort to help sort out the characteristics of intra-varnish organic matter, we explored the OCR procedure in varnish samples collected from the natural pavement adjacent to the Ripley geoglyphs (Fig. 2). Back-scattered electron microscopy revealed what is fairly normal: clasts with the field appearance of a well-developed varnish can host both unlayered and layered varnish (Fig. 6). Higher concentrations of organics and lower $\mathrm{OCR}_{\mathrm{RATIO}}$ values for unlayered varnishes in Table 6 may be explained by this and similar imagery. Layered varnish contains fossil biomolecular remnants and less frequently decayed casts of microbes involved in varnish genesis (Dorn 1998). In addition, layered varnish contains organic "carpetbaggers" – organics that percolate downward through the varnish and consist of a mix of older and contemporary organics. But unlayered varnishes also include pockets of concentrated younger organics in the "pits" typically dug by microbial acids. Thus, these pockets of younger organics generate both higher concentrations and lower $\mathrm{OCR}_{\mathrm{RATIO}}$ values. Table 6 compares $\mathrm{OCR}_{\mathrm{DATES}}$ for five successive layers scraped from rock varnish on two andesitic clasts at the Ripley site – collected about 30 m away from the geoglyphs. The lowest layers of each varnish includes material such as iron from the underlying rock, which may affect the Walkley-Black procedure (Walkley 1947, cf. Dorn 1997). Unlayered varnishes above this rock-contaminated layer reveal a fairly consistent signal. $\mathrm{OCR}_{\mathrm{RATIO}}$ values ranged from 6.3 to 9.7 with $\mathrm{OCR}_{\mathrm{DATES}}$ only a few hundred years old. The young $\mathrm{OCR}_{\mathrm{DATES}}$ throughout the varnish likely reflects the ongoing insertion of younger microcolonial fungi deep into the rock varnish (cf. Dorn 1994 and Fig. 6).

Layered varnish still reveals young OCR ages, likely far younger than the age of the varnish itself. Note, however, that there is a fairly consistent depth-trend. $\mathrm{OCR}_{\mathrm{DATE}}$ and $\mathrm{OCR}_{\mathrm{RATIO}}$ values increase with depth. In other words, ongoing replacement of younger organic carbon has some depth function. We suspect that this depth function represents the slow-downward movement of humic substances through the clay-oxide matrix seen in high resolution transmission electron microscopy (Dorn 1998). Thus, younger organics move through the varnish layers, concurrent with older organics experience ongoing diagenesis similar to the metabolic processes observed in the soils of mounds and ramparts discussed above that would make them less susceptible to leaching by Walkley-Black digestion.

Several aspects of Table 6 warrant notice. The $\mathrm{OCR}_{\mathrm{DATES}}$ for the unlayered sample are similar to, or relatively younger than, the top level of the layered varnish. This is not due to a scale problem in sampling, but probably two factors acting in tandem. First, rough surfaces with pitting facilitate deposition of organics within these "pits" as seen in Figure 6. Second, the microenvironments where pitting generally takes place are wetter and thus friendlier towards colonization by lithobionts that erode these pits. Therefore, these wetter locations promote faster, but pitted, varnish growth. These explanations are also consistent with lower pH values for unlayered varnishes. Lithobionts such as lichens and fungi secrete acids. The gradual increase in pH may reflect distance from the surface source of the organic acids.

In summary of this study, rock varnishes on and near geoglyphs serve as a sponge for, and habitat of, organic carbon undergoing diagenesis. Unlayered varnishes are analogous to vertisol soils with the opening of pits and insertion of organic matter deep into the soil and varnish. Layered varnishes are analogous to cumulic loess soils where humic acids and other carbon slowly migrates into an aggrading open system. Thus, radiocarbon ages and $\mathrm{OCR}_{\mathrm{DATES}}$ on both layered and unlayered varnishes are not likely

***Table 6**. Data from rock varnish layering study, near Ripley geoglyph site, Arizona. The site has a historical mean annual temperature of approximately 19.4° C and a mean historical annual precipitation of approximately 17 cm. The depth of each sample came from the upper centimeter. Varnish particle sizes are clay sized (Dorn 1998). OCR ages are reported in calendar YBP -- 1950 (cf. Frink 1992, 1994). Shaded entries indicate data emphasized in text.*

Sample	% C (LOI)	Percent oxidizeable carbon (WB)	OCR (Date)	OCR ratio	pH
Unlayered Varnish - Level 1	0.63	0.079	267	8.0	6.2
Unlayered Varnish - Level 2	0.48	0.076	240	6.3	6.1
Unlayered Varnish - Level 3	0.29	0.043	355	6.7	5.9
Unlayered Varnish - Level 4	0.35	0.036	444	9.7	6.8
Unlayered Varnish - Level 5	0.19	0.016	737	11.9	7.4
Layered Varnish - Level 1	0.30	0.022	680	13.6	7.2
Layered Varnish - Level 2	0.19	0.013	952	14.6	6.9
Layered Varnish - Level 3	0.11	0.006	1524	18.3	7.6
Layered Varnish - Level 4	0.08	0.0045	1708	17.8	7.9
Layered Varnish - Level 5	0.13	0.0043	2262	30.2	8.1

to reflect the age of the onset of varnishing. Rather they reflect the age of the various process that have occurred between the time of varnish inception and the present.

Ultimately, understanding natural systems of organic carbon mobility might open the door to modeling organic carbon retention in varnishes formed on geoglyph cobbles using depth profiles and OCR_{DATES}. In other words, just as MRT radiocarbon ages are sometimes used to model soil age, it may be possible to model the varnish age if rates of organic carbon exchange within varnish layers can be established independently. It is critical that these models are based only on layered varnishes that have consistent depth relationships. It is equally critical that organic carbon in the host rock not be sampled, because the host rock likely contains vitrinite and inertinite inherited from prior episodes of rock weathering (Dorn 1997; Dorn et al. 2001).

CONCLUSION

People around the world have expressed behavior through construction of monumental earthen architecture. Some constructions are aggradational, as evidenced by mounds and ramparts; others erode land surfaces, as evidenced by geoglyphs. The use of geological taphonomy to study cultural material contained with the structures limits our ability to understand cultural and historic contexts of earthen architecture. In contrast, pedogenically oriented studies demonstrate a more appropriate approach to study these constructions.

Traditional pedogenic studies, descriptive of soil characteristics, provide only an anatomical snapshot of these evolved constructions at the time of sampling. However, soils and weathering phenomena such as rinds and coatings may also be viewed physiologically as autopoietic, self organizing, systems – open to matter and energy transfers, but closed organizationally. The distinction between an anatomical and physiological approach is critical to the evaluation of archaeological sites. An anatomical analysis is essentially static, providing only an inventory of parts and their locations, while a physiological analysis dynamically interprets the interactive behavior of parts through time and through their functioning as a whole. This distinction is analogous to asking your doctor to stop diagnosing your medical condition based on a static inventory of your anatomy, and instead to base the diagnosis on a dynamic physiologically assessment of how your systems are functioning.

Soils and weathering phenomena as autopoietic systems are themselves artifacts of events with which pedogenic and weathering processes interacted and responded to; influence, but not cause, the unique trajectory of pedogenesis of the particular soil body or weathered phenomena. Human actions involved in the construction and maintenance of monumental earthen architecture are such events influencing soil and weathering. Application of frameworks and procedures sensitive to open system dynamics allow for a physiological analysis of dynamic processes of pedogenesis including the taphonomy of the soil itself, and the cultural material contained within the soil. Similarly, open system analyses facilitate physiological perspectives on weathering processes.

Through the presentation of several case studies in humid regions, we demonstrate the potential of the OCR approach to analyze open-evolving soil and weathering systems in locations of annual moisture surplus. Patterns in the variables used in the OCR procedure describe the movement of fine and coarse particles evolving into argillic and stone line horizons (texture), cultural amendments (pH and organic carbon), and time-dependent biodegradation of organic carbon (OCR_{RATIO}). These patterns provide new insights into monumental earthworks through interpreting how their construction and maintenance affect the open system of carbon diagenesis. Additionally, the calculated OCR_{DATE} provides a temporal context for these events.

While a physiological perspective offers unique views on aggradational monumental earthworks in humid regions of the planet, the virtual absence of insights into soil formation processes associated with geoglyphs in arid regions limits the direct interpretation of these soils as self organizing, autopoietic, systems. The OCR procedure offers a powerful conceptual model that may help fill this knowledge vacuum for geoglyphs and other arid soil, and soil-like processes such as varnish formation. Further studies on diagenetic pathways of organic carbon, standardization of procedures, and blind testing with other dating techniques are needed before a complete physiological characterization, and accurate and precise dating of these arid soils are possible. However, as the history of science shows, introducing the first, cohesive conceptual framework on which to hang empirical data accelerates our ability to build progressively more accurate models.

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