The Carbonization of Vegetation Associated with "Fire Areas," Mammoth Remains and Hypothesized Activities of Early Man on the Northern Channel Islands

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Abstract — The carbonized vegetation associated with Pleistocene "fire areas" and mammoth and bird fossils on the Northern Channel Islands has been attributed to wildfires and to the cooking of mammoths by humans. This paper elaborates on the hypothesis (Cushing *et al.* 1986) that such carbonization occurred in groundwater. Fire and water carbonizations are compared. A search for methods which distinguish directly between residues of these two processes is reported as unsuccessful, leading to the conclusion that, as with interpreting radio-carbon dated material, research on *in situ* circumstantial evidence is necessary in order to interpret carbonized residues as charcoal.

Introduction

An unusual feature of Santa Rosa and, to a much lesser extent, Santa Cruz and San Miguel Islands are Pleistocene red soils called "fire areas." As reviewed by Moratto (1984) in his chapter "The First Californians," these areas are the basis for arguments that some were cooking pits ("hearths") of man and others were caused by hypothetical ancient island wildfires. Moratto concludes, however, "...the notion of Pleistocene archaeology on the islands must be confirmed." The difficulties of such Early Man confirmations in general are well known (see Erickson *et al.* 1982).

We have hypothesized (Cushing *et al.* 1986) that many, if not all, of these "fire areas" were formed in groundwater. This hypothesis adds another factor to be evaluated in such a confirmation. The present paper elaborates on the section of our paper which argues that a clear distinction must be made as to whether the carbonized vegetation sometimes associated with mammoth and bird fossils at "fire areas" was carbonized in fire or in water. It describes some features of these two types of carbonization and reports the results of a search I have made for experimental methods which would make this distinction directly from the vegetation. The search included personal field and laboratory observations, an extensive literature review, and communications with persons in diverse disciplines as acknowledged at the end of this paper.

The Process of Carbonization

Vegetation is carbonized by oxidation. The principal endpoint of this oxidation is carbon dioxide, also produced by other processes in the carbon cycle, such as respiration, vulcanism and weathering. The carbonizing oxidation referred to here is either the result of fires (Wright & Bailey 1982) or groundwater events (Greensmith 1978), notably microbial metabolism (Johnson 1985). Neither of these oxidations usually goes to completion under natural (field) conditions. Rather, heterogeneously complex, dark, residues of condensed carbon compounds remain at any specific site. These residues often are altered by diagenesis (geological processes) varying with changes in their original *in situ* environment. Such residues are not always distinguishable as to their origin (see Cook 1964; Haynes 1967; Hillman *et al.* 1983; Riddell 1969; Shutler 1967). Additionally, on the islands, care must be taken not to confuse them with asphaltum lumps from marine oil seeps (Orr 1960; Berger 1980).

Fire

Charcoal is the general term for the carbonized residues of fires. This is accompanied by mineral residues, "ashes," which do not always persist as long as charcoal, being blown or washed away, or incorporated into soil. Many studies on the chemistry and commercial utilization of wood and coal show that a great variety of organic compounds is produced during burning. This differs greatly among such activities as cooking, heating, charcoal making, wood distillation and so on (Fengel & Wegener 1984; Higuchi 1985).

Approximate orders of magnitude of the temperatures(°C) of some kinds of heats are: human 37°; automobile engine 82°; boiling water 100°; kitchen gas burner 260°; camp fires 400-700°; ignition temperature of wildfires 300-400°; wild fires (which vary greatly above soil surface) 90-1430° and subterranean petroleum fires 1000-1500°. These temperatures are not absolute, but are widely diverse depending upon a multiplicity of environmental conditions.

Fundamentally significant are the facts that heated air rises and that wild fires usually move along "fronts" during periods of less than an hour. Any one place beneath them is therefore maximally heated for only a short time and at temperatures well below that of the fire itself. Subsurface temperatures usually become ambient in a matter of minutes and at depths of less than 5 cm. These conditions rarely are sufficient to noticeably redden (oxidize) earth.

Rather, earth is reddened (but not always, see Orr 1968; Shutler 1967) only if heated by outdoor fire "hot spots" which persist for orders of magnitude of days rather than minutes or hours. Such fires are sustained pyres and large, cooking-fire pits (Orr 1968) or, in the aftermath of wild fires, long-burning slash piles, logs, stumps and roots (Wendorf 1982). However, Orr's experimental island fires only maximally reddened earth for some 15 cm after two days, and mainland prolonged stump fires only for some 50 cm. Such maxima are not usual, also the fire reddened areas are of sporadic distribution, and limited in diameter, and do not necessarily persist over time (Orr 1968).

In contrast, the numerous island "fire areas" we have studied are typically continuous, often overlying, beds which may extend for several meters up to several kilometers, with depths varying within a bed between 2.5cm to over one meter. We have seen that their erratic exposure by erosion can create an impression of separate pits and other discontinuities. Their soil is not baked or fused, but consists of unheated clays, sand and gravels. Had these been caused by fire, the massive sustained heat required would have been comparable to that of subterranean petroleum fires which can burn for years, but these fuse rocks and earth, are restricted in extent and have not occurred in the Quaternary island sediments where "fire areas" are found. Vulcanism also has been excluded as having acted in these sediments. As a matter of fact, the island "fire area" beds we have seen simply look as though they were precipitates formed by some relatively unique process (probably microbial action on water-logged vegetation).

Groundwater

The Chaney & Mason (1934) fossil vegetation locality in Sauces Canyon on Santa Cruz Island, dated 14,200 ±250 yr B.P. (UCLA-144), provides a remarkable "field laboratory" for the study of carbonization in groundwater. We note (Cushing *et al.* 1986) that "There, many pieces of carbonized wood ranging from fragments through twigs to branches and logs were often associated with moderate red (5 R 4/6, U.S.G.S. color key) to moderate yellow (5 Y 7/6) sediments." Extensive studies (both field and laboratory) by ourselves and members of the Geological Sciences Department, University of California, Santa Barbara, led to the conclusion that this carbonization and related phenomena were the results of non-thermal events ≤100°C. Similar studies on the classical Santa Rosa Island "fire areas" at or near the Orr (1968) and Berger (1980) locales showed that the properties of these overlapped and did not differ qualitatively from the Sauces Canyon locale or each other. Two mammoth molars also have been reported by us (Cushing *et al.* 1984) near the Sauces locale.

Small, swamp-like areas (cienagas) occur on the islands today, as well as masses of vegetation washed by annual rains into streams and brackish estuaries at their mouths. Both these features also occurred in the Pleistocene, giving rise on Santa Rosa Island, for example, to ferric casts of reeds associated with Arlington Man and hundreds of bones of the extinct "giant" island deer mouse, *Peromyscus nesodytes* Orr (1962). Orr (1968) further reports that in 1947 "...there were numerous logs and branches of trees a short distance up Caada Tecolote. These were quite rotten and very black in color and occurred in a small cienaga or swamp-like bend in the creek and appeared to be relics of an historical forest. The following year we found other logs and branches buried in the 40 foot cliffs of the arroyo." These were identified by Chaney as a cypress species no longer growing on Santa Rosa and radiocarbon dated "at 15,000 years in age (L-244)."

We could not find any carbonized wood at this locale, although fragmental mammoth remains were common; we presumed the plant fossils had eroded away. We have observed that erosion also is washing the Chaney & Mason material downstream into the sea, and mingles the fossils not only with modern vegetation, but with the bones of cattle, sheep, and at the stream mouth, of marine animals.

Fortunately, a compensatory discovery of ours under study is a new fossil carbonized vegetation locality, reported here for the first time, which is being exposed upstream from the Chaney & Mason site.

These observations illustrate how readily plant and animal remains of very different ages can come to be associated by secondary depositions. In fact, our first discovery of a mammoth molar (Cushing *et al.* 1984) was in the Pozo Canyon stream bed, Santa Cruz Island, on its way to the sea, as were the two mammoth molars in Sauces Canyon and the mammoth fossils we have found on Santa Rosa.

Diagenesis

Diagenesis adds a complicating dimension to carbonization. This can in part be due to microbial activities (Krumbein 1983). Most significantly on the islands, fossil plant and mammoth remains appear to be in secondary, wet, sedimentary depositions. One diagenetic alteration is that some carbonized vegetation has become hardened at Christy Beach and on Santa Rosa Island. Further, we describe (Cushing *et al.* 1986) mineralizations and alteration of fossil wood at the Chaney & Mason site to the degree that this will not burn, although giving off an odor suggestive of the burning "punks" used to ignite fireworks, but becomes reddened and magnetic when heated over a stove burner.

Roots, which had grown down later among the Chaney & Mason vegetation as shown by their vertical positions, also were carbonized.

Not excluded is the hypothetical possibility that, as with subterranean peat and coal fires elsewhere, both fire and water have in some areas acted on island fossil vegetation.

MacKenzie & co-authors (1982) discuss the diagenesis of carbonaceous molecular compounds and how these are to be considered as chemical fossils which eventually will be useful in determining the nature of their original sources. This area of research shows both the complexity of diagenetic change at the molecular level and the great potential this work has for resolving questions of the sort asked in this paper.

Radiocarbon Dating

Many radiocarbon dates have been reported for both plant and animal Channel Island fossils. These include a recent one of 10,290 ±110 yr B.P. (AA-1268) from wood, not carbonized, collected by Wenner beneath and in contact with the mammoth tusk from Santa Cruz Island now exhibited in the Santa Barbara Museum of Natural History (Wenner *et al.* 1991). We have stated (Cushing *et al.* 1986) that the interpretation of island dates should be re-evaluated considering the groundwater hypothesis, secondary deposition, diagenesis, and recently established criteria for evaluating such dating.

The point has been made repeatedly by some archaeologists and radiocarbon dating laboratories, not only for radiocarbon dating, but for archaeometric data in general (see Taylor & Payen 1979) that the interpretation of such data, being obtained with ever increasing accuracy, requires interdisciplinary field research performed *in situ* on circumstantial evidence at the time of the collection of the dated material. Otherwise most archaeometric dates *per se* are of limited value. An example of this point, particularly in view of the variable submergences and emergences of the Channel Island shore lines, is given by Schell (1983). He obtained $\delta^{13}C$ and ^{14}C values on materials from Alaska estuarine food webs involving peat where delays of several thousand years between primary production and use by ecosystem consumers can occur.

Experimental Methods

The sections above show the need for experimental methods that will determine whether residues of island carbonized vegetation are the result of oxidation in fire or in water. So far, even though this need has long been generally recognized (see Oakley 1956), I have found only two experimental studies on the problem.

The first of these was by Cook (1964). He determined the amounts of elemental (fixed) carbon in visually indistinguishable residues from archaeological sites, hypothesizing that these amounts should be greater in fire than in water carbonization. However, an ecological spectrum of values from site to site has apparently prevented the development of his hypothesis.

More recently Hillman and his colleagues (1985) have shown that cereal grains from historically known archaeo-logical sites could be differentiated as to the temperature of their carbonization by comparing the electron spin resonances (ESR) of radical carbon obtained from them (see also Sales *et al.* 1987) However, as with evolving archaeometric methods (see Taylor 1987), the general ap-plicability of this method is still be determined.

Possible bases for developing comparative methods do appear to exist in several diverse areas. Patterson & his colleagues (1987), for example, present an extensive evaluation of the use of microscopically particulate charcoal in the study of the paleoecology of wildfires. They conclude that such methods show great promise, especially as the microscopic record can be validated against other methods common in Quaternary research. The differentiation of microscopic charcoal from decay carbonizations apparently cannot yet be made experimentally but this may not be necessary in many cases, as for example, where wind has deposited a clearly demarked layer of particles. A concluding proviso of the authors' notes that further advances will depend upon the efforts and judgments of many individuals respecting specific studies.

Another promising base (which conceivably might come to be combined with studies such as those above) is research on chemical fossils (see Leo & Barghoorn 1970; MacKenzie *et al.* 1982) which is beginning to identify organic compounds that, even though subject to diagenesis, were originally derived from living organisms.

Additional potentials lie in research on the anatomy of plant fossils (see Siegleo 1978; Stubblefield & Taylor 1986) and plant materials at archaeological sites (see Prior & Alvin 1983). Another potential subject is the organic chemistry of charred wood (see Shafizadeh & Sekiguchi 1983). These few specific examples, of course, should be considered against the general background of the chemical and physical methods used in soil analyses (see Greenland & Hayes 1981), in studies on the ecology of bogs (see Johnson 1985), on the processes of coal formation (see Greensmith 1978) and on the commercial utilization of wood (see Fengel & Wegner 1984; Higuchi 1985).

The current lack of direct comparative methods which could be applicable to Channel Island research is not surprising for several reasons, including the following three: 1) such methods may not be necessary in many studies; 2) their need may not have been recognized in others and 3) their development is challenging because of the complexity and variability of the residues involved.

To conclude, it is apparent that the Channel Islands offer an essentially unexplored area for research on the differentiation of the processes for carbonization, especially as these relate to paleontology, archaeology,ancient wildfires and the activities of groundwater processes. It also is apparent, however, that at present, as with the archaeological interpretation of radiocarbon dates in general, the differentiation of the origin of carbonized residues on the islands must be made from circumstantial evidence obtained *in situ*, and the term "charcoal" should be carefully applied.

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Prehistoric Predation on Black Abalone by Chumash Indians and Sea Otters

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Abstract - Present populations of black abalone (*Haliotis cracherodii* Leach) at Santa Cruz Island, California are presently dense, up to 90/m^2. Examination of shell middens created by Chumash Indians suggests that such high present-day densities may have developed recently after the elimination of the black abalone's two cardinal predators: Chumash Indians and sea otters (*Enhydra lutris*). The size distribution of abalone in existing populations is skewed towards large individuals (>100 mm) whereas shells from midden populations are smaller (<80 mm). A difference in predation intensity may account for the disparity in population characteristics between historic populations and contemporary populations of black abalone. Intense intraspecific competition among black abalone, as well as certain behaviors, may be recent developments following reduction in predation intensity. If so, black abalone may be experiencing relatively new selection regimes.

Introduction

The degree to which predators affect their prey populations is an ecological question of considerable interest. Numerous studies have examined the constraining effect that predation may have on prey density and body size (see Gause 1934; Huffaker 1958; Connell 1961; Elson 1962; Paine 1974; Peterson 1979; Schmitt 1982, 1987). Other studies have shown that the prey may also limit predator densities (see Gause 1934). In this paper I consider the potential influence two predators may have had on populations of the black abalone (*Haliotis cracherodii* Leach). Specifically, I explore whether abalone densities and body sizes may have shifted following changes in predation pressure.

The sea otter, *Enhydra lutris*, is a well known nearshore predator along the coast of California that can limit the distribution and abundance of one or several of its prey (Kenyon 1969; Wild & Ames 1974; Estes *et al.* 1981). In the subtidal region, sea otters can dramatically affect densities and microhabitat distribution of several abalone species (Ebert 1968; Wild & Ames 1974; Breen *et al.* 1982; Hines & Pearse 1982), including black abalone (Estes *et al.* 1981). Prehistoric man also preyed upon black abalone and may have significantly impacted intertidal populations (Wilcoxon 1992). Both of these predators were active along the shores of the California Channel Islands including Santa Cruz Island.

Chumash Indians began inhabiting the Channel Islands around 7,500 years B.P. (Glassow 1980), but perhaps even as early as 37,000 B.P. (Orr 1968). Abalone and other shelled invertebrates were collected by Chumash as food, and shells were discarded into vast piles, termed middens. These often were located directly above the site where the animals were gathered, although some middens were on hilltops, several miles from shore (Wilcoxon 1992; Douros unpubl. obs.). The shell collection in middens represents a record of foraging by Chumash. By examining archaeological samples containing *Haliotis cracherodii* shells, I estimated the size structure of black abalone populations from thousands of years ago. Presently, high density populations of black abalone commonly occur at Santa Cruz Island, ranging in density from 80-100

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