

The Interpretive Potential of Micromorphological Analysis at Prehistoric Shell Midden Sites on Camp Pendleton

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Abstract

Micromorphological analysis of archaeological sediments from three coastal sites aided in elucidating the degree of integrity and the nature of contextual associations that characterize these prehistoric sites. Previous model of site formation constructed by Gross 1992 for San Diego county is tested through this new geoarchaeological study. The results of the study demonstrate that the precise composition of sediments in which prehistoric cultural materials are situated cannot be predicted a priori according to geotopographical setting. Thus, one cannot assume that sites in non-depositional settings with subsurface cultural materials and no fine-scale stratigraphy will lack significant anthropogenic deposition.

Introduction

This paper summarizes preliminary results from geoarchaeological research on sediments associated with three large shell midden sites situated along the central coastline of Camp Pendleton (Goldberg 1996, 1997). Conducted as a part of a larger research investigation (Byrd 1996, 1997), this study employed micromorphological analysis to aid in understanding the degree of integrity and the nature of contextual associations that characterize these prehistoric sites. Specifically, these issues included the degree and type of bioturbation, the extent that sediments were anthropogenic and geogenic in origin, an evaluation of the formation of sediments associated with unusual subsurface features, and the testing of prior hypotheses that predicted the type of formation process for sites within particular geotopographic settings. Anthropogenic sediments are archaeological deposits (both organic and inorganic: e.g., lithics; bone, shell, charcoal, ash) produced as a result of human activity, such as construction (e.g., walls, floors, middens) or trash dumping. In contrast, geogenic refers to sediment of geological origin, such as alluvium or aeolian sand. Finally, bioturbation is the mixing of soil or sediment by the activity of animals (e.g., burrowing).

An important aspect of archaeological research has entailed discerning the varied role of natural and cultural formation processes on the character and integrity of archaeological sites and their stratigraphy (e.g., Gifford-Gonzalez et al. 1985; Schiffer 1983, 1987; Villa 1982). Cultural factors such as discard patterns, human treading or trampling, and the digging of pits for cooking and construction can significantly alter the spatial distribution and integrity of artifactual material prior to abandonment. In addition, a series of natural factors and bioturbation (such as alluviation, erosion, and animal disturbance) can have a significant effect on the character of archaeological sites (e.g., Rick 1976; Schiffer 1987; Courty et al. 1989; Wood and Johnson 1978:318-320).

Discerning the role of these natural disturbance processes on site formation has been a particularly important research issue in California (Erlandson and Rockwell 1987; Erlandson and Yesner 1992: 267-269). Rodent disturbance is probably the most notorious of these transformation processes, and recent research has documented the magnitude of the effect it can have on archaeological sites (Bocek 1986, 1992; Erlandson 1984; Johnson 1989). Extensive rodent disturbance can obfuscate and otherwise obliterate behaviorally meaningful intra-site spatial distributions and other cultural features such as floors and hearths. Rodent disturbance may also create significant non-random patterns in the vertical distribution of artifacts, while having only limited effect on horizontal distributions. Rodent induced vertical spatial patterns are related primarily to artifact size, weight and relative material density (Bocek 1986:600-601). Typically, the smallest artifacts are filtered upward in the "backdirt" of the rodent burrowing, while the largest artifacts are avoided. The latter then drop downward when burrows collapse below them, ultimately creating a "level" of heavy artifacts near the base of the main rodent burrowing.

Recently, Gross (Gross 1992; Gross and Wade 1998) has reviewed and discussed site formation processes with respect to this portion of Southern California. A rather provocative aspect of this presentation entails the interpretation of sites in non-alluvial settings. At its essence, Gross's (1992:195-199) argument is that San Diego County coastal sites in nondepositional environments will typically lack in situ subsurface cultural deposits. Exceptions to this model of site formation will be characterized by the presence of intact, observable, and complex stratigraphy, notably lenses of shell with minimal associated sediment. Sites with marine shell dispersed in sediments are considered to lack in situ subsurface deposits (Gross 1992:198-199). For example, the presence of considerable subsurface cultural material at a case study site, SDI-1103, is interpreted to be the result of bioturbation processes (primarily rodents), and these processes mimicked depositional processes with cultural material temporally ordered by depth. One of the major implications of such interpretations is that observed vertical patterning of buried material culture do not have stratigraphic and cultural implications. The oldest artifacts will have been reworked vertically downward the greatest, due to their age. Younger artifacts will be found closer to the surface.

This study provided an ideal opportunity to test this model of site formation. A total of 31 micromorphological samples were collected from three shell midden sites on Camp Pendleton: SDI-811 (N=2), SDI-10,726 (N=9 including 6 from Locus A and 3 from Locus B), and SDI-10,728 (N=20) (Goldberg 1996, 1997). The three tested sites vary considerably in size (ranging from 26,000 m² to 315,000 m²) and in spatial complexity. Considerable quantities of buried cultural materials are present at all three sites, although the thickness of the deposits and presence of features varied considerably. By contrasting samples from archaeological occupation on top of a ridge (SDI-10,726 Locus B, SDI-10,728 Locus A), in a swale of a ridge (SDI-10,726 Locus A, SDI-10,728 Locus B), and in an alluvial setting (SDI-811), the micromorphological study aimed at providing data to address this issue. Samples were collected to micromorphologically characterize the sediments of the different geological units

and make inferences about primary (i.e., depositional) and secondary (i.e., post-depositional) processes.

The Micromorphological Approach

Archaeological investigations typically employ field observations of color, texture, structure, and consistency as useful descriptors to provide criteria to surmise the conditions of development for a soil or archaeological sediment. These data alone are intrinsically limited in their ability to make definitive interpretations and their sole use could result in erroneous conclusions. One strategy employed to supplement and strengthen field observations involves analyses of grain-size and chemical analyses, such as pH, calcium carbonate, organic matter, cation exchange capacity, and soluble and exchangeable ions.

One factor that limits the usefulness of interpreting both the field and laboratory data, is the typically complex nature (e.g., composition) of soils and sediments associated with archaeological sites. What, for example, is the significance of a grain-size analysis of a “grey,” “ashy” dump deposit, commonly found in archaeological sites such as the ones studied in this project? The results generated by a grain-size analysis in such a case do not discriminate between the mineral (e.g., quartz sand, silt, etc.; calcareous ash crystals; phytoliths; bone) and non-mineral components (charcoal, or disseminated organic matter), and one would simply observe a poorly sorted sediment. Moreover, a similar analysis of a colluvium would not indicate that the material might have been transported in aggregated form, since grain size analysis attempts to break down the sample into its primary components. Finally, most of these techniques also are limited in their ability to recognize and discern a succession of pedological, geological or anthropogenic events that have been superimposed upon the same material or substrate (a certain analysis may be valid only for one of these events). For example, at the field scale, a dark layer within a Holocene archaeological site context may represent a soil horizon, an occupation layer, or both. Measurement of Munsell color or organic matter in this case, does not really help (Courty et al., 1989). Similarly, a calcium carbonate analysis may comprise primary (depositional) or secondary (pedogenic) carbonate.

A technique that is proving increasingly valuable for avoiding many of the above-mentioned limitations is that of micromorphology, the study of undisturbed soils, sediments and other archaeological materials (e.g., ceramics, bricks, mortar) at a microscope scale. Micromorphology employs undisturbed, oriented samples in which the original components and their geometrical relationships are conserved. Micromorphological analysis allows for the observation of composition (mineral and organic), texture (size, sorting), and most important, fabric (the geometric relationships among the constituents). Within an individual thin section it is therefore possible to observe micro-stratigraphic sequences which reflect temporal changes in depositional and post-depositional processes, such as sedimentation followed by bioturbation and then clay translocation. Such sequences would be difficult to monitor using more conventional techniques.

This technique requires samples to be collected in the field as undisturbed blocks, roughly 10 by 7 by 7 centimeters (cm). These blocks are then imbedded in epoxy or polyester resin from which 2 by 3-inch thin sections are prepared (in this case by Spectrum Petrographics, Oregon). The thin sections are then examined with microfiche viewer and petrographic microscope under plane polarized (PPL) and cross-polarized light (XPL), at magnifications ranging from 10x to 200x. Observations were noted using the descriptive terminology of *The Handbook of Thin Section Description* (Bullock et al. 1985) and Courty et al. (1989). Photographs of these thin sections are best presented in color, although for practical reasons in this article they are presented in black and white.

SDI-811

The Red Beach site (SDI-811) lies at the western end of the Las Flores Creek flood plain, extending from directly west of Interstate 5 to within 50 meters (m) of the beach, and from the edge of the creek on the south across the entire flood plain to the north. This large site (315,200 m²) has a low to moderate surface density of artifacts and marine shell, comprised primarily of *Donax*, along with a range of artifacts. Test excavations in the southeast area provided evidence of a potentially complex array of buried archaeological material within the Las Flores Creek alluvial deposits (Byrd 1996; Rasmussen Foster 1999). The vertical distribution of cultural material was strongly patterned and varied from being absent to extending to a depth of 110 cm. High densities occurred at depths from 40-110 cm associated with two subsurface pit features encountered in excavation units 1 and 2 (mean shellfish density per m²: 10,978 kg). The three radiocarbon dates on *Donax gouldii* shellfish indicate occupation during the early half of the second millennium B.P., uncalibrated (maximum 2 sigma calibrated date A.D. 530-970) (Byrd and Reddy 1999: Table 2), and earlier occupation is also well-documented (Rasmussen Foster 1999). Two micromorphological samples were collected from excavation unit 2.

Micromorphological Observations

Unit 2 revealed three main deposits, with the upper 60-70 cm, deposit 1, characterized by a very dark greyish brown compact loam with considerable quantities of cultural material, particularly below 40 cm. At 70 cm, a dispersed distribution of fire-cracked rock occurred throughout much of the unit associated with a compact sandy silt layer termed deposit 3. This had been cut into by a pit feature, deposit 2, and the features contained bone, fire-affected rock and ground stone fragments (including a series of stone bowl fragments at its base). A culturally sterile compact silty sand was encountered at 100 cm.

Two thin sections were analyzed; one from the pit feature, deposit 2, and one from the adjacent sediments of deposit 3. The sample from the fill of the pit feature revealed visual differences discernible between it and the adjoining sediment of lower strata were slight. The other

sample comes from adjacent stratigraphic deposit 3 which was largely devoid of cultural material.

The sample from deposit 2 is composed of poorly sorted sand and silt size material, and only trace amounts of finer material. The coarse fraction is comprised of two fractions: an angular to subangular coarse sand composed of quartz, feldspar, and some rock fragments, and a finer fraction, made up fine sand to coarse silt size grains of quartz and feldspar, and lesser amounts of biotite and hornblende. No signs of original bedding are present. The fine fraction occurs only in trace amounts and consists of patchy, very thin and very fine-grained pellicular dusty coatings around grains; due to the fine size of the coatings, it is not possible to evaluate their composition with the optical microscope (pellicular refers to the very thin coatings around grains). Porosity is produced by intergrain voids, resulting in essentially a single grain structure (voids are the empty spaces between solid components, such as pore spaces left by decayed roots). Post-depositional features are limited, and expressed as localized, irregular, splotchy micritic (microcrystalline calcite) hypocoatings that are about 75-100 m thick. Hypocoatings represent impregnations of soil or sediment with secondary material (e.g., secondary calcite) originating from open space (e.g., pore space) within the soil or sediment. Some of the voids (empty spaces between solid components, such as pore spaces left by decayed roots) associated with these hypocoatings contain remains of modern roots, suggesting that the hypocoatings are of relatively recent origin. This sample represents an essentially unweathered geogenic sediment, and there are no signs of any anthropogenic influence such as bone, or ash. The few hypocoatings are of recent origin.

The deposit 3 sample is virtually indistinguishable from the previous sample. It differs slightly in having two angular splinters of bone and in showing a slight increase in finer grained material, which locally forms bridges between grains of the coarse fraction. No calcareous hypocoatings were observed. There is very little difference between this and the deposit 2 sample, except for the presence of two bone fragments. As such, it could represent redeposited sediment from which the deposit 2 sample was taken, locally mixed with some bone. A large anthropogenic influence is not evident in either sample despite the presence of a structural feature and the moderate densities of shellfish and faunal remains.

SDI-10,726

SDI-10,726 (the Las Flores Ridge top site) is situated immediately west of Interstate 5 on a remnant Pleistocene marine terrace. The site overlooks the mouth of Las Flores Creek and SDI-811 lies directly to the northwest. Covering nearly 26,000 m², the site includes two loci. Locus A covers 1500 m² dominated by *Donax* shell along with sparse flaked lithic area. Locus B occupies much of the remainder of the ridge line to the east, covering an area of 19,000 m², and includes a more abundant and diverse range of stone artifacts and marine shell (the latter primarily represented by *Chione*, along with *Argopecten* and *Donax*).

Test excavations revealed a complex series of occupation events (Byrd 1996). Excavations in Locus A produced a maximum of 95 cm of archaeological deposit consisting of a sandy loam with a moderate density of *Donax* shell (mean shellfish density per m², 12,522 kg). The deposit is homogeneous with no clear indications of multiple use episodes or buried surfaces. Associated with the shellfish are low frequencies of flaked stone artifacts, ground stone, fire-affected rock, vertebrate remains and paleoethnobotanical remains. A single radiocarbon date from the testing phase indicated Late Prehistoric occupation (see Byrd and Reddy 1999: Table 2).

Excavations in Locus B revealed two major phases of occupation (Late Prehistoric and early Archaic), and intact features (and a shellfish density in unit 5, the deepest unit, of 54,978 kg per m²:). The upper phase appears spatially restricted to the western portion of the locus, while the lower deposit is much more extensive. The upper phase is characterized by dense concentrations of *Donax*, along with *Argopecten*, and *Chione* in association with prehistoric ceramics, flaked stone artifacts, and small amounts of ground stone and fire-affected rock. The lower archaeological deposit appears to have a more complex spatial structure, and *Donax* is largely absent. Moreover, it contains higher frequencies of artifact classes, vertebrate faunal remains and paleoethnobotanical remains. Dating of a series of samples reveal post-depositional mixing between the two phases of occupation—a Late Prehistoric *Donax* midden, and an early Archaic shell midden (see Byrd and Reddy 1999: Table 2).

Locus A Micromorphological Observations

Six micromorphological samples were taken from Locus A, three from each unit. Excavation unit 1 is situated on a slightly south-sloping eroded Pleistocene fluvial terrace remnant. Overall, the sediments consist of three intact geological units, in addition to a fourth which is comprised of loose, disturbed surface material within the upper 10 cm. The section displays gravelly ashy deposits that are locally cemented, but in parts are friable. There is a possible dip to the south-southeast which would indicate colluviation from the north-northwest. The major question under consideration is, how much of the sediment is cultural and how much is geogenic?

Deposit 1 is the upper 10 cm surface material, while deposit 2 is a hard but friable ashy silt with numerous pebbles and *Donax* shells about 2 cm across. Deposit 3 is similar to deposit 2 but softer, slightly darker in color, less cemented, less stony, and with finer shell fragments; it looks ashy. Deposit 4 is a hard, cemented but friable, sandy gravel; sterile Pleistocene fluvial sediments.

All the micromorphological samples from this excavation unit are similar. There is some variability in the proportions of the coarse and fine fractions, and to a lesser extent the related distribution (the geometric relationship of the coarse and fine fraction in the sample). The coarse fraction is characterized by a poorly sorted mixture of rock fragments and grains

ranging in size from silt to fine pebbles. They vary in shape from angular to subrounded. Composition is very diverse ranging from individual silt and sand sized grains of quartz to rock fragments composed of phyllite and various volcanic rocks. These also vary from fresh to moderately weathered. Another component is biological in origin, represented by angular millimeter to centimeter size shell fragments (presumably *Donax*); other biologically-related grains, such as bone, are quite rare. The finer fraction is remarkably low in most of these samples, and varies from sample to sample. The fine fraction usually occurs either as interstitial fillings with either gefuric or enaulic related distributions and is composed of dark brown clay and numerous microcontrasted particles that cannot be resolved with the optical microscope (Interstitial refers to the void space between solid grains. Gefuric refers to the fine material that occurs as braces or bridges between coarse material, while enaulic refers to the fine material that occurs as interstitial aggregates between coarser grains).

It is presumed that much of this fine fraction is very finely divided organic matter. In the descriptions below, mainly the differences between the units will be noted. The porosity in most of these samples is characterized by a bridged grain or pellicular microstructure; the fine fraction is never abundant enough to completely fill the interstitial voids. No micro-stratification was observed in any of the samples. These samples are obviously quite uniform in character and exhibit only minor variations in composition, texture and fabric. The virtual absence of any culturally-related elements, such as bone, suggests that this is primarily a geogenic deposit, and as such seems to have accumulated naturally, with only limited human intervention.

Excavation unit 4 has similar stratigraphic division as in excavation unit 1, and generally the sediments appear to be gravels that were simply mixed with ash and then reworked by biological activity including a disturbed surface layer, a lighter brown ashy gravel with gravel pockets; darker brown fine ashy gravels with relatively little cultural material, and sterile gravels at base. Micromorphology samples were taken from the upper three geological units.

The deposit 2 sample, in contrast to the samples from excavation unit 1, the finer fraction here is noticeably richer in blackish-brown organic matter, presumably charred. This composition shows that these samples have more of a "cultural" aspect to them which is something not evident in the field where sediments from both units were similar. The deposit 3 sample looks very similar to those from excavation unit 1 where the coarse fraction exhibits patchy pellicular coatings of fine dusty brown material. The deposit 4 sample is similar to the deposit 2 sample, with a slightly higher proportion of coarse elements within the coarse fraction. Overall, these are slightly richer with respect to organic content than those from Unit 1.

The samples from excavation unit 1, for example, are quite uniform, and do not exhibit any significant variations in composition or texture. The samples from excavation unit 4 are for the most part similar, although they seem to be slightly richer in organic matter. Both sets of samples indicate only minor cultural influence on a primarily geogenic deposit.

Locus B Micromorphological Observations

Three micromorphological samples were analyzed. Two from Unit 5 and one from a feature in Unit 6. Excavation unit 5 is situated at the top of the hill in the eastern part of the site. Exposed at the base are sterile, massive silty sands overlain by ca. 75-85 cm of crumbly, massive and generally ashy fine gravels; these are riddled with sub-horizontal rodent burrows, particularly in the middle portion of the profile. The sterile sediment is generally finer grained than in excavation units 1 and 4. Overall, there are basically three deposits. Deposit 1, from 0-64 cm, consists of a very dark grayish-brown gritty, ashy, sandy gravel, punctuated by isolated, mostly burnt, angular and rounded stones ca. 6 cm in diameter. *Donax* shells start at ca. 20 cm below surface and are quite fragmented; they are more complete at a depth of ca. 60 cm. Extensive burrowing occurs below a depth of ca. 25 cm, down to the base of the geological unit. Many roots occur in burrowed areas. Contact with underlying unit abrupt where intact, but burrowed in most places. Extensive earthworm burrowing evident.

Deposit 2, 64-94 cm, is a compact ashy silt with numerous large shells and smaller shell fragments. It's lighter grey at top, grading down to more brownish and softer massive silt. The grey color and hardness at the top is probably due to the presence of ash. Numerous roots are present laterally with some rodent burrows up to ca. 15 cm in diameter. The transition to deposit 3, which is essentially archaeologically sterile, is gradual. Deposit 3, 94-120 cm, consists of a marbled brown and dark grayish brown silts with numerous shells in burrows. Several cm-size vertical burrows are present that resemble those of cicadas. Portions are less bioturbated, and mostly with cicada-type burrows.

Two micromorphological samples were analyzed, one each from the upper geological units. The micromorphological sample from geological unit 1 reveals evidence of extensive burrowing on the microscopic scale (Fig. 1). This takes the form of earthworms casts, which are characterized by the presence of rounded aggregates, and bow-like passage features. Indications of burning are represented by burnt shell fragments, reddened pieces of matrix, and fine sand-size pieces of carbonized material. The latter are also finely comminuted and have been worked into the fine fraction by biological activity, resulting in the dark brownish color of the matrix of this sample. Thus, field observations of extensive burrowing for this sample are confirmed in the microscope with earthworm casts and bow-like features. Furthermore, the fragmentation of the *Donax* shells observed in the field could be produced by this burrowing, and it's worth noting that many of the shells (as well as bones) in the slide from this layer exhibit rounded ends, possibly resulting from bioturbation and abrasion by movement in the soil. Since the fine fraction is non-calcareous, no signs of ash were observed and it is not clear whether this sample was never really ashy, or has been decalcified.

The sample from deposit 2 when viewed mesoscopically with incandescent illumination or with a hand lens, strongly resembles that of excavation Unit 6. Both have calcareous fine fractions, that are rich in finely divided organic matter. In addition, both exhibit numerous

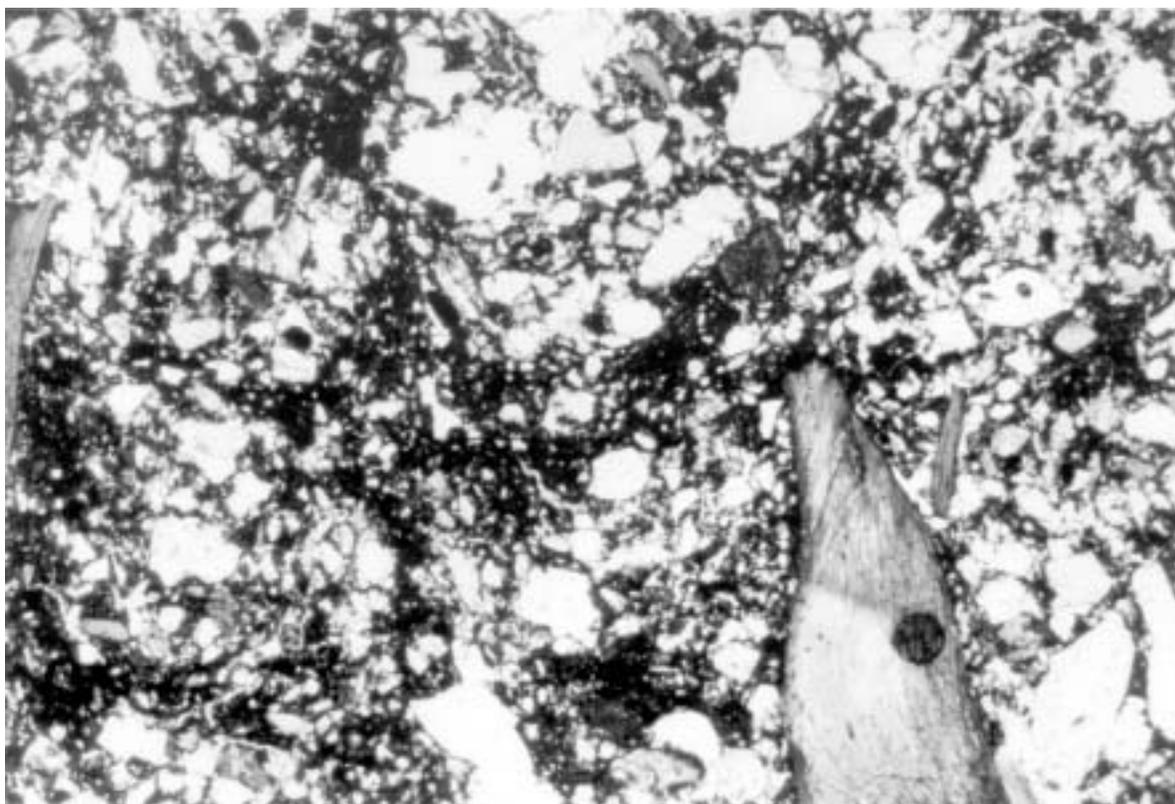


Fig. 1. Micromorphological sample from SDI-10,726 Unit 5, deposit 1. Bioturbation is illustrated by a bow-like passage feature figured in the center of the photograph. Note the dense packing of the fine fraction associated with this feature, as well as its dark color produced by the integration of very fine pieces of carbonized material resulting from bioturbation. Also present is a large shell fragment to the right. Plane polarized light, two times magnification.

hypocoatings and calcite laminae. In this sample, however, the laminae are distributed differently within the slide. Whereas in Unit 6 they were in thin to thick beds, in this sample, they occur in a hemispherical/horseshoe-shaped void or cavity, and in this sense appear to line what would normally resemble a hole made by an insect, such as a mud-dauber, or less likely, a cicada. In other words, although it appears to be a chemical precipitate, it is more likely that it was biologically produced by an insect. Numerous, less distinct semicircular “coatings” occur in the slide and presumably represent former, not partially collapsed insect holes. The dimensions and shape are not dissimilar from that of a cicada (of which, a cicada burrow can be observed 3 cm from this on the slide). As well, individual ash rhombs (rhombus-shaped grains) can be found (although these were difficult to photograph), indicating that the calcareous nature of the sample is associated with ashes and burning; field observations suggested that these were ashy deposits. Calcined shell and relatively numerous bone fragments (still <1%) also indicate an anthropogenic aspect of this sample. In addition to cicada burrows,

earthworm casts were also observed, providing further evidence of biological activity and burrowing.

The interpretation of this material is similar to that found in the Unit 6 sample, which is essentially an anthropogenic sediment that has been extensively modified by burrowing, either by earthworms, and/or by cicadas and possibly wasps. The latter two would be responsible for producing the calcareous laminae observed in both these samples. The extent that such burrowing affects the integrity of the archaeological assemblages cannot be estimated from these samples. Archaeological data would be more diagnostic in this regard, such as lithic analysis revealing mixed assemblages, or refitting studies.

One sample was taken from the ca. 1.5 m diameter burnt rock feature in Unit 6 of Locus B (Fig. 2). The sample was collected from the whitish layer, ca. 6 mm thick, that occurs as a patch about 10 cm across at the base of the feature. Next to this patch is a more globular piece, possibly associated with krotovina and pecten shell and ash, with apparent micro-layering. This compact sample contains numerous (but still <1%) splinters of sand-sized bone. Some of this bone shows signs of having been heated, and some of the shell fragments show signs of partial calcination. The sample is noticeably richer in fine material than the previous samples to the point where the related distribution is porphyroskelic (the coarse fraction floats in the ground mass). It is rich in microcontrasted particles, probably from burnt vegetal material; an abundance of phytoliths can also be seen. It is also quite calcareous which is notably unlike any of the samples described above. Calcium carbonate occurs throughout the fine fraction predominantly as fine grained micrite. As well, individual rhombs of calcium carbonate derived from wood ash can be seen (Courty et al. 1989). Calcium carbonate also occurs as hypocoatings (impregnations of calcium carbonate from the edge of the void inward through the matrix), which are associated with roots; in one void the remnant of a root can be seen. These hypocoatings could be recent phenomena.

Calcium carbonate also occurs as mm-sized grains that contain quartz silt and also exhibit a wavy to clotted aspect. Some of these wavy forms range from 500 Fm to 5 mm thick and seem to occur on old fracture surfaces, but the sample is not large enough to fully discern their arrangements. Their wavy pattern is reminiscent of algally precipitated calcrete or pendants beneath stones; to a lesser extent they also are reminiscent of patterns associated with plaster.

From the micromorphological point of view this is clearly a cultural deposit. This is shown by the presence of bone, burnt shells, ash crystals, phytoliths, and very fine-grained (silt-sized) remains of charcoal. Judging from the finely comminuted size of the charred material, it appears that this sample has been extensively reworked by soil fauna, such as cicadas. In fact, certain portions of the slide, when viewed macroscopically show centimeter size aggregation of the matrix which is identical to that produced by cicadas in the Keatley Creek site, British Columbia (Goldberg 2000).

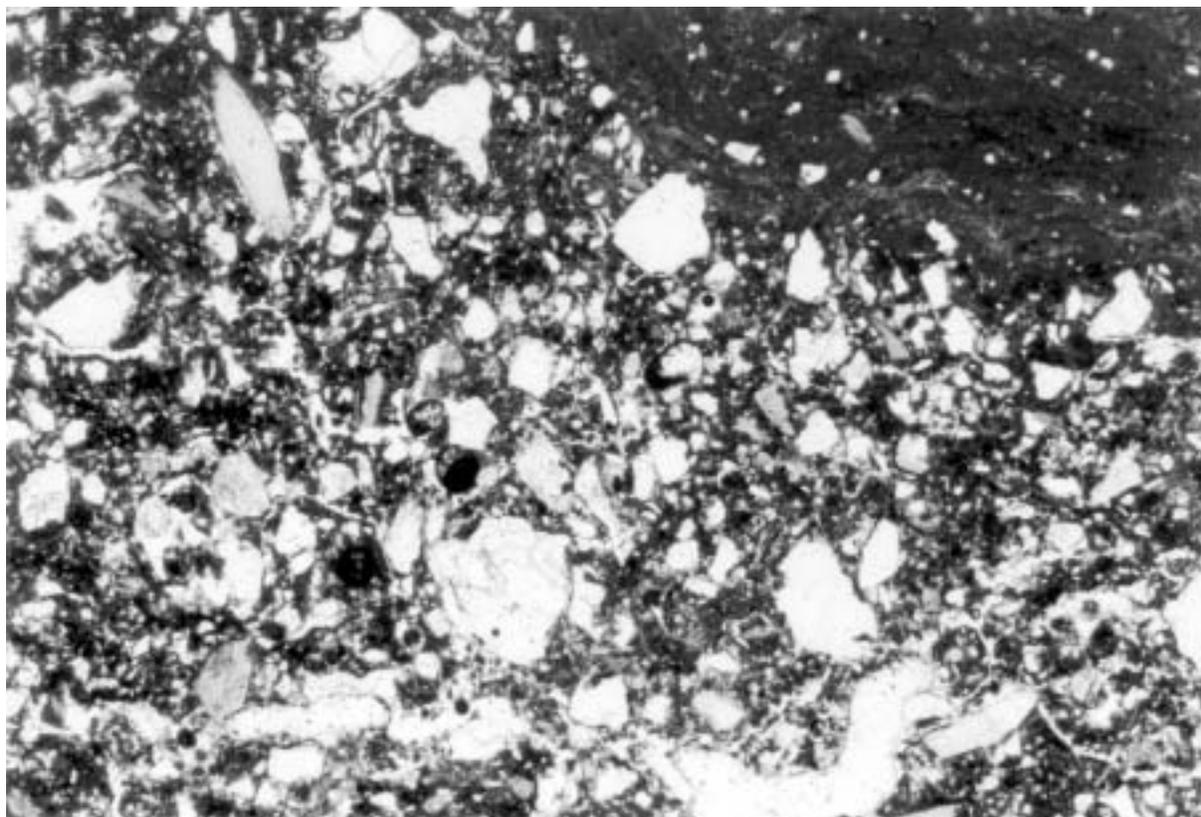


Fig. 2. Micromorphological sample from SDI-10,726 unit 6. Note the dense fabric and the bone fragment in the upper left hand corner. In the upper right hand corner is a calcareous, finely laminated accumulation. Cross polarized light, two times magnification.

The hypocoatings represent remobilizing of calcium carbonate along root passages. Most of these are probably relatively recent, as shown by the presence of fragments of modern roots within them. The laminar layering of calcite is more problematic. On the one hand, they appear most similar micromorphologically to laminar calcretes, but such an interpretation does not match the field observations that indicated globular-shaped calcareous material. This laminar crust is also not widespread enough over the site for it to be reasonably interpreted as a large-scale soil feature, such as a calcrete crust. The appearance in the Unit 5, deposit 2 sample (see above) of similar material associated with centimeter size semicircular voids suggest that it is more likely of biogenic origin. In this sample however, the laminae are much thicker and could therefore be of anthropogenic origin, such as redistribution of ashes or even a plaster. Again, the globular appearance in the field would suggest that this calcium carbonate feature is produced by humans and not natural aggregation of calcareous ashes.

SDI-10,728

SDI-10,728 is situated on top of the ridge overlooking the lower reaches of Las Flores Creek directly east of Interstate 5 and SDI-10,726. The site covers an area of 30,500 m² and consists of two loci. Locus A covers 5,000 m² while Locus B is limited to only 1,030 m². Locus B, slightly down slope at the west end of the ridge, is quite localized in area, and potentially affected by colluvial runoff from the hilltop to the northeast. In contrast, Locus A is situated along the crest of the ridge further to the southeast, and there is more limited geogenic source for sediment deposition.

Excavations within the larger Locus A revealed a complex accumulation of cultural material representing at least two major occupational events (Byrd 1997). The upper deposit within Locus A consists of highly bioturbated anthropogenic sediments with dense quantities of marine invertebrates along with moderate quantities of lithic artifacts, ground stone, shell beads, and fire affected rock. In the western portion of Locus A, *Donax* dominates the upper deposit, while elsewhere *Donax* are infrequent and *Chione* and *Argopecten* predominate. The lower deposits, extending to a maximum of 100 cm also include high frequencies of marine invertebrates and moderate quantities of artifacts and fire affected rock. *Chione* and *Argopecten* predominate in the lower deposit throughout Locus A. In Units 3 and 5 a prominent cemented calcrete lens separates the upper and lower deposits. Elsewhere calcrete occurs as thinner, discontinuous laminae in the lower deposit. The four dates from Unit 3 are early Archaic. The three dates from Unit 5 reveal that *Donax* exploitation dates to the Late Prehistoric period, while *Chione* exploitation dates to the early Archaic (although considerably later than documented in Unit 3) (see Byrd and Reddy 1999: Table 2).

Excavations in Locus B revealed a single relatively homogeneous cultural deposit approximately 40 cm thick deposit and highly bioturbated. It includes dense concentrations of *Donax* shell (mean shellfish density per m², 12,522 kg) along with low frequencies of vertebrate fauna, macrobotanical remains, flaked stone artifacts, ground stone, shell beads, and fire-affected rock. The two radiocarbon dates from Units 1 and 2 place occupation in the Late Prehistoric period (see Byrd and Reddy 1999: Table 2).

A total of 20 samples were collected and analyzed from excavation units in Locus A (16 samples) and Locus B (4 samples). Only the results of samples from two excavation units are presented below as examples, although the broader discussion draws on all the samples analyzed (Goldberg 1997).

Locus B Micromorphological Observations

Samples from excavation unit 2 are presented. The stratigraphy for Unit 2 in Locus B was simple. Deposit 1 was a very dark brown organic silty loam extending to almost 40 cm, and it was underlain by deposit 2, the Pleistocene terrace sediments. The deposits were extensively

bioturbated and krotovina are present throughout, particularly in deposit 1. The highest marine invertebrate densities occurred from 10 to 30 cm (4,813 g and 5,287 g, respectively). Although four samples were analyzed, only one sample from each deposit is discussed here.

A sample from deposit 1 revealed that the coarse fraction is portrayed by a poorly sorted mixture of coarse sand-size lithic fragments to smaller grains ranging down to silt size; they vary in shape from angular to subrounded. Composition ranges from individual silt and sand-sized grains of quartz to rock fragments composed of phyllite and various volcanic rocks that are fresh to moderately weathered. *Donax* shells are illustrated by angular mm-cm size fragments that occur in small amounts ($\sim <5\%$); bones are quite scarce. The fine fraction ($\sim 5-10\%$) is composed of dark brown clay and numerous microcontrasted particles that are not resolvable with the optical microscope. It appears generally as interstitial fillings between the larger sand grains, either with gefuric (fine material occurs as braces between coarse material) or enaulic (the fine material occurs as interstitial aggregates between coarser grains) related distributions; the fine fraction is never abundant enough to completely fill the interstitial positions. It is presumed that much of the fine fraction is comprised of very finely divided organic matter that is responsible for imparting the darker color of this sediment in the field. Much of this finely divided organic matter resembles that of the residues of burned, ashy materials. However, due to the non-calcareous nature of the sample (*Donax* shell is the only calcareous component), (calcitic) ash is not present. The porosity in most of these samples is characterized by a bridged grain or pellicular microstructure; no microstratification was observed, and in fact, the loose nature of the sediments indicates extensive bioturbation as was suggested in the field.

The deposit 2 sample mirrors the observations in the field, where the dense, lighter silty clays of deposit 2 were dotted with mm size brown spots. In thin section, the lighter colored material is expressed as a poorly sorted slightly clayey, silty sand. The interstitial material in this "sterile" sediment is cleaner and overall contains less silt size organic matter. In addition, the greater clay and fine mica content is reflected in a speckled and granostriated b-fabric. There is no evidence of any clay coatings (argillans), however, which would be indicative of clay translocation and soil development.

Perforating this cleaner material, are sharply defined circular domains a few mm across that are comprised of the same organic-rich interstitial material found in deposit 1; this material is clearly derived from it, as insinuated in the field. These domains also tend to be somewhat less compact and with a looser aggregation of coarse grains; they also locally exhibit some sand size grains of broken charcoal. This sample is virtually non calcareous (except for one *Donax* shell), and one can only assume that any trace of calcrete has been eroded from this basal sediment at this position.

Locus A Micromorphological Observations

Samples from Unit 3 were studied. The excavations extended to 1.03 m and five stratigraphic deposits distinguished. Deposit 1 extended to 60 cm depth, and consisted of crumbly, bioturbated organic clay that varied from very dark gray near the top to very dark grayish brown at the base. This deposit was highly disturbed and included dense concentrations of shell, and moderate amounts of artifacts and faunal material were present. Deposits 2 and 3 were layers of dense, laminar, white calcrete, with the upper consisting of two to three discontinuous, thin calcrete lenses that undulate. Deposit 3 was an extremely hard calcrete lens approximately 3 to 5 cm thick that formed an impermeable cap over the lower sediments that rodents and roots were unable to penetrate. This deposit included a considerable amount of highly calcified shell, many of which were whole or large fragments of *Chione* and *Argopecten*. Deposit 4 consisted of a grey brown fine grained gravelly silt that ranged in thickness from 15 to 30 cm. The moderate quantities of recovered shell included more complete shells than in the upper levels, along with debitage and marine shell beads. Deposit 5 consisted of yellowish brown fine to medium silty clay that appeared to be primarily comprised of the underlying Pleistocene terrace. Marine invertebrate quantities steadily decreased with depth, associated with a small quantity of debitage.

Micromorphological observations for the deposit 1 match those from the field: abundant, loose, aggregates composed of sand and silt with a dark brown clayey matrix, rich in finely divided organic matter (Fig. 3). There are numerous shell fragments and many appear to be etched. Teeth fragments were also observed. The matrix is non-calcareous and there are no signs of any secondary carbonate. There is one grain of a broken carbonate nodule presumably reworked from lower levels. Some of the matrix is locally brighter red which could reflect evidence of burning.

The sample from the deposit 1/deposit 2 interface is very complex, and no doubt the bioturbation has mixed these contrasted sediments. The matrix is similar to that which was observed in samples from other excavation units in that it seems to be a mixture of darker and lighter domains that represent more and less finely divided organic matter, respectively. Shell fragments are quite common but tend to be represented by sand size angular chunks that seem to be relatively fresh. The most complex and intriguing aspect of this sample is the nature of the secondary carbonates, which are represented by a number of different types. One type is represented by carbonate hypocoatings that as elsewhere appear to be rhizoliths (calcified roots); this type is relatively rare in this sample. A second type is represented by more dense micritic (microcrystalline calcite) impregnations that form bands about 2 to 3 mm thick and are composed of sand size rounded reddish brown pellets, similar to those from other carbonate zones. This type follows the bioturbated casts observed in the previous samples. In this sample, they tend to be subhorizontal, matching the surface of the sample. The third type is characterized by finely wavy microlaminated calcite that resembles stromatolites. These bands are quite thick reaching almost 2 cm in thickness. They also appear to represent more than one

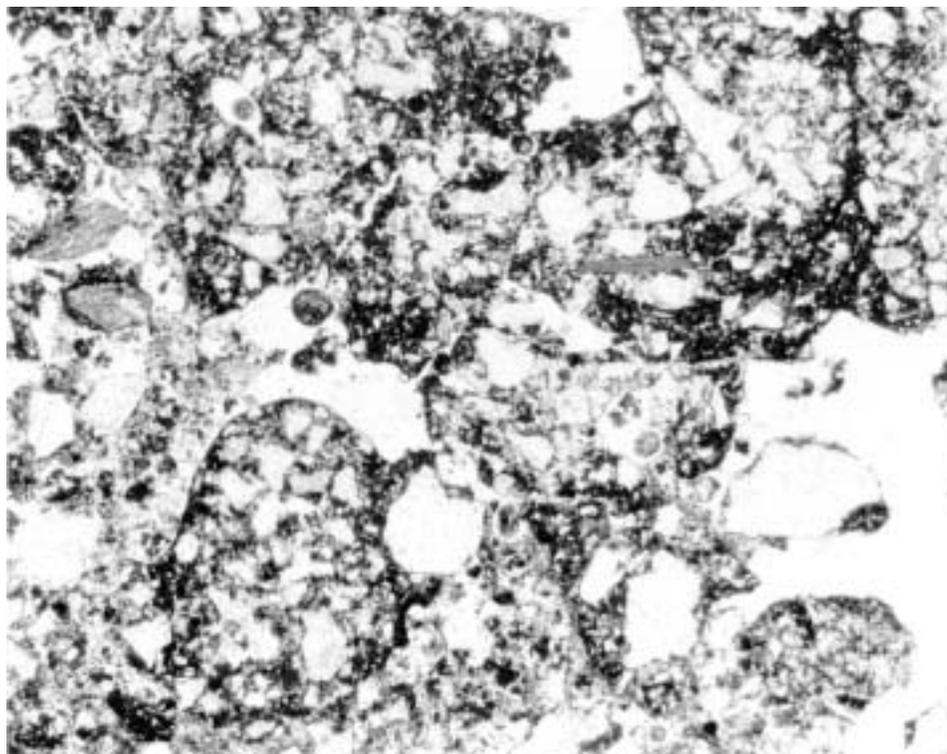


Fig. 3. Micromorphological sample from SDI-10,728 Unit 3, deposit 1. This sample exhibits loose, organic-rich composed of sand and silt with a dark brown clayey matrix. These loose aggregates resemble those produced by earthworms and contrast markedly with passage features found below Deposit 1, which are possibly produced by cicadas; these lower sediments are also more compact and with little void space. Plan polarized light, width of field ~ 3.5 mm.

generation because one set cross cuts the other set. This laminated type resemble macrostalactitic vadose cement that are observed in calcrete hardpans. This latter type could also have a biological origin such as algae but in any case, these are all subaerially produced carbonates. Shell fragments appear to be cemented by the latter two types of carbonate precipitation, and it appears that the laminar phase is the latest since it occurs on the globular phase. A few rhombs of calcareous ash were noted, but much of the sediment is non-calcareous so it is possible that this ash is much more widespread.

The deposit 3 sample is virtually identical to the deposit 1 sample. There appear to be slightly more reddish zones than in deposit 1 sample. The bones are also very badly altered. In contrast, the deposit 5 sample is overall similar to that of the deposit 3 sample, although this has much less well-developed secondary carbonates (Fig. 4). Some hypocoatings, however, do occur as well as diffuse micritic impregnations. A number of sand size fragments of bone were observed, as well as mm size pieces of fragmented shell. The presence of bone and shell in this supposedly sterile layer is most likely a result of extensive bioturbation which is strik-

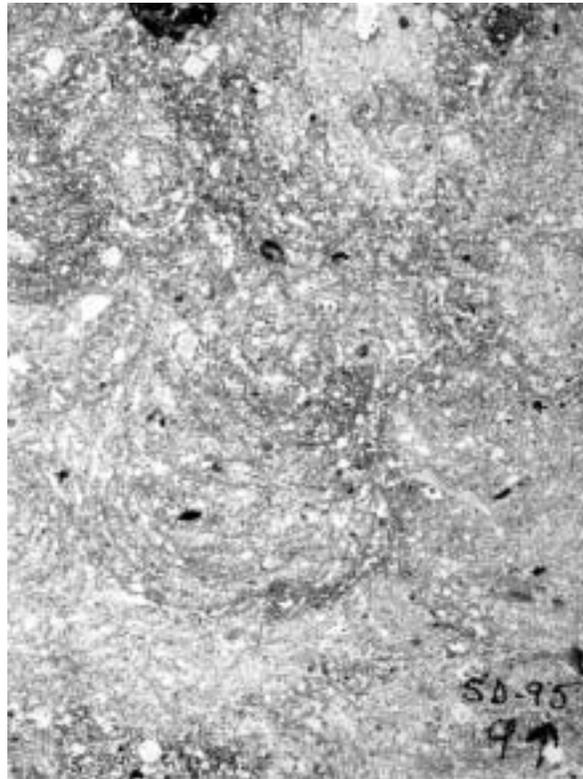


Fig. 4. Micromorphological sample from SDI-10,728 unit 3, deposit 5. Macro-photograph illustrating extensive bioturbation with many passage features; some of the highlighting of these features is enhanced by the precipitation of secondary carbonate, thus indicating that calcification post-dates bioturbation. Plane polarized light, length of field ~ 75 mm.

ing at the mesoscopic (x10) scale. In this sample, as in others, carbonate is preferentially precipitated along the boundaries of the bioturbated clusters, again showing that calcification postdates most or part of the bioturbation. Pelletal carbonate, similar to that observed in deposit 3 sample can be observed. The bioturbation is also responsible for the very compact nature of the sediment.

When the results of samples studies from other excavation units are included, there are clear micromorphological similarities that are visible in the different deposits regardless of the excavation unit. The lower deposits (such as in unit 3 deposit 5) exhibit traces of calcitic grains which are currently being decalcified. In other words, the thin sections from these deposits suggest that these are the vestiges of the original “sterile” sediments that form the base for most of the overlying occupations. Inclusions of bone and shell may have been introduced by bioturbation after the sediment had begun to be decalcified. These deposits are ones that have been subjected to some pedogenesis followed by accumulation of the overlying middle deposits whose cultural elements (bone and shell) were worked into it by bioturbation.

Secondary carbonate is also present in the lower deposits as hypocoatings, and nodular and pelletal carbonate; however, the secondary carbonate seems to appear as localized concentrations in the thin section. In light of the state of the shell and bone, this deposit appears to be older and more “aged” than the ones above. In other words, there seems to be a certain amount of time missing between the accumulation between the lower deposits and those above.

Above these lower deposits, the matrix is essentially non calcareous and richer in fine grained darker dusty organic matter. The secondary carbonate is much better developed than in the lower deposits and is expressed as either thick hypocoatings nodules and pellets or wavy microlaminated calcite. Most of this carbonate is precipitated along contacts of aggregates produced by bioturbation, and it is clear that in all slides examined that some bioturbation preceded the carbonate precipitation phase. Moreover, the fact that bone occurs within the aggregates and is rarely cemented by the carbonate indicates that occupation clearly predates the phase of carbonate precipitation. The matrix in these samples tends to be quite compact and the bioturbation aggregates and passage features tend to be on the order of 1 to 2 centimeters across; they resemble certain bioturbation features observed in the Keatley Creek Site in British Columbia where bioturbation was produced by the western cicada. The fact that the calcite precipitation postdates some of the bioturbation and occupation further supports the notion of a temporal hiatus between the lower deposits and the middle deposits and the accumulation of the secondary carbonate. This time gap was not particularly evident in the field.

The upper deposits (deposit 1) appears to be the freshest overall and richest in organic matter which imparts a dark color to these uppermost sediments. The accumulation of these sediments is associated in part with burning activity as observed in finely divided remnants of charcoal and the remains of partially dissolved rhombs of calcareous ash. It is likely that burning occurred through much of the accumulation of the upper deposits, although any remains of calcareous ash has been removed by dissolution (e.g. deposit 2 sample). The fact that the samples are quite loose could point to active bioturbation at present and also that there is no overlying material which would serve to compact the deposit. Moreover, the size of the biologically produced aggregates in these upper samples is smaller than those from the middle deposits. This small size could reflect a type of bioturbation associated with a different animal (they do resemble earthworm casts). The reasons for this shift in type of bioturbation (cicadas to earthworms) is not clear. The change could be a function of the amount of organic matter in the upper deposit and needs to be investigated further.

The formation of the so called caliche bands and lenses that are so prominent in the middle deposits and less so in the lower deposits is problematic. The carbonate would appear to be part of a former B or C Horizon. It is not clear whether deposit 1 (i.e., the associated A Horizon) is the source of this carbonate. It is possible that the carbonate was derived from the dissolution of deposit 1 because this deposit is largely non calcareous. However, the timing of this “caliche” formation is not clear.

Conclusion

The micromorphological analysis results from these three sites is quite enlightening. The small number of samples analyzed from SDI-811 are for the most part geogenic, and with the exception of some modern calcareous hypocoatings and scraps of bone, little evidence exists for pedological or anthropogenic modification. No remains of ash or burnt shell or bone were observed from the pit feature micromorphological sample. Thus, geogenic alluvial sedimentation with associated bioturbation is the dominant depositional type. However, the presence of remnants of structural features demonstrates that occupation occurred in place and material was not transported by fluvial processes.

The Red Beach site (SDI-811) is contained within alluvial sediments. Thus, this lowland area was aggrading through sheetwash and minor shallow channel deposition during periods of prehistoric occupation. The existing creek bed has cut into the site as a much later event, probably postdating 1800 A.D. The Las Flores Creek area has a complex and deep buildup of Holocene alluvial deposits reaching 4 m in depth and extending back to the fifth millennium B.P. (Waters et al., 1999). These silts and silty clays are the product of combined alluvial and pedogenic processes that have been further modified by bioturbation (Waters 1996). The structure of these sediments represents a complex interplay between continuing alluvial deposition, sheetwash, and pedogenesis. As a result, there is little internal structure visible in the upper strata although there may have been many discrete depositional episodes originally represented. The excavations have provided insight into a complex array of buried archaeological material and features within alluvial deposits, and sheetwash and fluvial processes have buried these materials under a discontinuous silt lens resulting in a complex vertical sequence across the flood plain.

With respect to Locus A at SDI-10,726, both sets of samples indicate only minor cultural influence on a primarily geogenic deposit. Although the samples from excavation unit 1 are quite uniform, they do not exhibit any significant variations in composition or texture. The samples from excavation unit 4 are for the most part similar, although they seem to be slightly richer in organic matter. Thus, it appears that the accumulation of sediments in Locus A of SDI-10,726 were largely due to geogenic processes, namely colluvial slopewash from the top of the ridge. That is not to say that the occupation events that resulted in the discard of the marine shell and other remains in Locus A actually occurred on the crest of the ridge and were fully washed down—these activities may have occurred in situ in Locus A, essentially in a depositional context. If further excavations in Locus A recovered in situ features, such as hearths, then this inference would be confirmed.

In contrast, the micromorphological analyses of samples from Locus B at SDI-10,726 reveal a different pattern. The samples from excavation units 5 and 6 are calcareous and exhibit much greater anthropogenic and biogenic influence in the form of bone, ash, finely divided organic matter and extensive bioturbation. It is not clear why other samples from the same excavation

units are not similarly calcareous, since no noticeable differences in these samples were observed in the field. Secondary decalcification is an unlikely cause because shell fragments are well preserved and do not appear to be etched. Alternatively, it is possible that these calcareous “layers” are tied to specific anthropogenic activities, such as burning, but they are not discernible in the field because of the masking effects of finely divided organic matter within the fine fraction. Any original noticeable differences in stratification between these calcareous and non-calcareous units have been blurred by extensive bioturbation. This has been produced by rodents, earthworms, and insects (cicadas and possibly wasps).

It is particularly noteworthy that Locus B is situated on top of a ridge and therefore is not a likely candidate for any geogenic inputs. In other words, it seems likely that most of the accumulation there is a function of human activity, not geological. Unfortunately, the specific human activities that might have produced this accumulation have been obliterated by extensive bioturbation. Nevertheless, this study demonstrates that past human activity is responsible for changes of the local landscape, even if on a small scale.

Cultural deposition built up in situ in this area. This inference is based on several lines of evidence including the absence of a likely candidate for geogenic deposition (except perhaps aeolian sediment), the presence of a structural feature (the hearth remnant in unit 6) with horizontal and vertical limits, and micromorphological evidence for anthropogenic components in the sediments from Unit 6 and the lower phase of Unit 5 in the form of ash, finely divided burnt organics, and bone. It is important to note that these empirical observations were possible despite the presence of considerable bioturbation, created by rodents, earthworms, and insects. Thus, the model of site formation for SDI-10,726 Locus B entails periods of intensive occupation that resulted in the accumulation of a thick occupation deposit (over 90 cm) comprised of two major phases. These deposits are strongly anthropogenic in origin, and were also subject to considerable bioturbation. Hence, if discrete lenses of marine shell had existed originally, they have been defused by bioturbational processes.

Turning to SDI-10,728, both loci revealed buried cultural deposits. Micromorphological analysis indicates the cultural deposits in the smaller Late Prehistoric Locus B are anthropogenic, with considerable charcoal and fine organics that appear to be the residues of burned ashy materials. Extensive bioturbation is evident on the macro and micro level. Based on limited testing, these very homogeneous deposits revealed no clear indications of multiple use episodes or buried features.

The larger and more structurally complex Locus A has considerable quantities of cultural material extending from 0.6 m to 1.1 m below the surface. Based on the micromorphological analysis, the upper two deposits exhibited a strong anthropogenic contribution with finely divided charcoal and calcareous ash. No features were present but the potential exists for their being present. Disturbance process, both natural and modern, have undoubtedly mixed these cultural material. This includes rodent burrowing (noted throughout), earth worm activity

(primarily in deposit 1), and possibly cicada burrowing (noted in deposit 2). Considerable cultural material has been bioturbated into the lower, Pleistocene deposits. After the early Archaic deposits had built up, secondary carbonates accrued probably as a result of leaching from the cultural deposits. In places, such as Unit 3, this formed a thick impenetrable layer that essentially served as a barrier for later movement of material. Elsewhere, secondary carbonates are less well-developed in deposit 2. Based on micromorphological observations, this carbonate formation occurred after the cultural deposits had been bioturbated. Such carbonate formation has been noted on many early Holocene sites in this portion of southern California (e.g., Roth and Berryman 1993; Shumway et al. 1961; Smith and Moriarty 1985).

In sum, this study has demonstrated that the precise composition of sediments in which prehistoric cultural material are situated cannot be predicted a priori based on geotopographic setting. Instead, rigorous analytical techniques should be employed to characterize the sediments, and micromorphology provides an ideal tool to conduct such investigations. The micromorphological samples studied in this pilot investigation have revealed dense cultural material present in: geogenic dominated sediments in an alluvial, deposition setting (SDI-811); geogenic dominated sediments in the swale of ridge (SDI-10,726 Locus A); anthropogenic sediments in the swale of a ridge (SDI-10,728 Locus B); and anthropogenic sediments deeply buried on two ridgetops (SDI-10,726 Locus B and SDI-10,728 Locus A). Therefore given this complex situation, one cannot assume that sites in nondepositional settings with subsurface cultural materials and no fine-scale stratigraphy will lack considerable anthropogenic deposition. Anthropogenic deposition can predominate in the formation of the deposits, and at the same time these deposits can be bioturbated to various degrees. Utilizing such results, much more complex models of site formation can then be developed.

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Comments on the Interpretive Potential of Micromorphological Analysis at Prehistoric Shell Midden Sites on Camp Pendleton

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The paper by Goldberg and Byrd on micromorphological analysis, like the use of geoarchaeological data, is illustrative again of the willingness of Camp Pendleton researchers to adopt a range of analytical tools in an effort to understand site formation processes. An intriguing aspect of micromorphological analysis, for instance, is its potential for discerning natural from anthropic sediments. Given that the structure of coastal archaeological deposits in southern California routinely are obscured by bioturbation and non-cultural sources of deposition, micromorphological analysis affords a more accurate and reliable way of discerning cultural stratification than the simple visual inspection that archaeologists often use for this purpose. Equally important, Goldberg and Byrd show that the presence of microscopic fragments of bone, shell, and vegetal matter can be highly informative about technoeconomic patterns that might otherwise escape detection altogether. Micromorphological analysis appears to be a technique that will grow in importance as cases such as the Camp Pendleton research become better known to archaeologists.