

Cave Sites in Northeastern Luzon, Philippines: A Preliminary Soil Micromorphological Study



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INTRODUCTION

THIS ARTICLE DESCRIBES A STUDY of soil micromorphological thin sections from the archaeological sites of Eme and Dalan Serkot Caves in the Cagayan Valley, northern Luzon, Philippines, in the context of their local and regional significance. The samples were taken as part of the first author's Ph.D. research, investigating Palaeolithic-Neolithic transitions in the northern Philippine region (Mijares 2005a, 2006), but also form a comparative collection for cultural cave sediments from the southern Philippines and Borneo, which are being investigated by the second author (Lewis 2003, 2007). Both of these projects focus on understanding the prehistory of cave occupation and how changes in this reflect larger-scale movements of people, cultural materials, and ideas in the Island Southeast Asian region, with an aim to relate cave sites to the wider landscape through a variety of approaches, including geoarchaeology and the location and excavation of contemporaneous open-air sites.

BACKGROUND TO THE STUDY

Northeastern Luzon is composed of a large basin called the Cagayan Valley, which is circumscribed by the mountains of the Sierra Madre in the east, the Cordillera Central in the west, and the Caraballo range in the south (Fig. 1). The Sierra Madre is an inactive volcanic arc with peaks up to 1800 m, while the active Cordillera Central has peaks up to 3000 m. The Cagayan Valley, which is dissected by the northward flowing Cagayan River, is composed of marine, transitional marine, and non-marine volcanoclastic sediments (Mathisen and Vondra 1983). The cave sites discussed here are found in the Callao limestone formation, which runs along the western foothills of the Sierra Madre. This formation consists of a 540 m thickness of reef carbonates formed during the late Miocene

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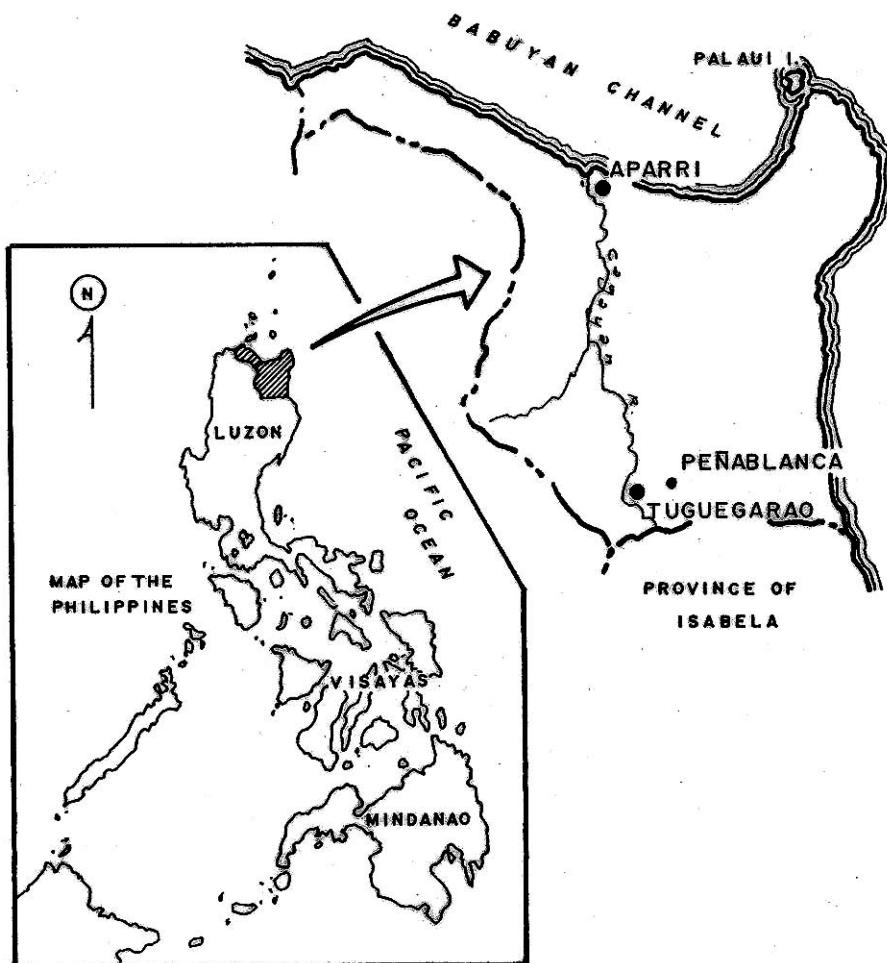


Fig. 1. Map of the study area. (Courtesy Mijares 2006).

to early Pliocene (Durkee and Pederson 1961; Mathisen 1980). Eme and Dalan Serkot are two of numerous caves in the Peñablanca area; according to Wasson and Cochran (1979) the Peñablanca caves are phreatic solution caves, with sponge work and cavities as common features.

ARCHAEOLOGICAL BACKGROUND OF THE CAGAYAN VALLEY

The Northeast Luzon region is in an important location regarding both the early movement of people into the Philippines, and the spread of Neolithic farming and later metal age cultures. The earliest human remains in the Philippines (*H. s. sapiens*) have been found at Tabon Cave on Palawan Island in the southeast, and

recently dated to c. 47,000 B.P. (Dizon 2003; Fox 1970). Exactly when early hunter and gatherer groups reached Luzon in the north is still unknown. Chopper and pebble scrapers found in the Cagayan Valley (Cabalwanian industry) are thought to be associated with middle Pleistocene megafauna assemblages (Fox and Peralta 1974), but these were found in secondary alluvial deposits, and might actually be of late Pleistocene date (Reynolds 1993; Shutler and Mathisen 1979). A new AMS radiocarbon date of $25,968 \pm 373$ uncal B.P. (Wk14881) on charcoal for Callao Cave, associated with flake tools (Mijares 2005a), is so far the oldest evidence of human cultural remains in northern Luzon.

The overall local model is of early forager activity dating back at least to 25,000 B.P., with caves being used by people from the earliest known times. Both cave and open-air occupation sites are known from the latest Palaeolithic period, through into the Neolithic period and later. Luzon lies just south of Taiwan, one proposed route for the spread of Austronesian cultures into the region (Bellwood 1997, 2004). Cultural material thought to be from Taiwan appears around 4000 B.P., attesting to interaction between the island peoples in the area. Rice, at least as temper in pots, is known from the same period, and rice agriculture is thought to enter this region (and the rest of Island Southeast Asia) from the north.

Hung (2004) hypothesizes that the greatest interaction between Taiwan and Luzon occurred around 4000 B.P., corresponding to the Middle Neolithic of Taiwan and the Early Neolithic of Luzon. The Fushan Phase (c. 4000–3500 B.P.) of the eastern Taiwanese middle Neolithic is characterized by a decrease in fine cord-marked pottery and an increase in red-slipped pottery. Red-slipped pottery appears in the archaeological record of northern Luzon around 3500 B.P. (Aoyagi et al. 1993; Ogawa 2002; Snow et al. 1986; Tsang and Santiago 2001).

A number of caves in the Callao limestone formation were excavated from 1976–1982, and again in 1999. In 1976, archaeological exploration of the Callao limestone formation in the municipality of Peñablanca recorded 43 caves and rockshelters with cultural remains (Ronquillo and Santiago 1977). Excavation of nine cave sites in the late 1970s and early 1980s showed at least two major phases of cultural deposition in the caves (Mijares 2001, 2002; Ronquillo 1981; Thiel 1980, 1987, 1989). The lower cultural deposits of these caves are generally characterized by andesite and chert flakes, with the faunal remains of deer and pig and riverine gastropod shells; the upper deposits contain the same materials with the addition of earthenware pottery. The caves excavated at this time were Rabel, Laurente, Alejandro Malanos, and Pedro Pagulayan in the south of the area (Henson 1977; Ronquillo 1981), and Arku, Musang, Lattu-Lattuc, Callao, and Minori in the north (Cuevas 1980; Mijares 2002; Thiel 1980, 1987, 1989). In 2003 two new cave sites were excavated in the Callao formation, namely Eme and Dalan Serkot, both in the southern section (Mijares 2005a), and the subject of this article.

In the Cagayan Valley, a number of open-air and shell midden sites have also been surveyed and excavated. Red-slipped pottery with rice inclusions was found at the Andarayan site, and dated to 1450 B.C. (Snow et al. 1986). Most of the other sites investigated in the valley also contained red-slipped pottery, underlying later shell midden deposits with black pottery, the latter dating to c. 2000 B.P. and later (Aoyagi et al. 1993; Ogawa 2002; Tsang and Santiago 2001).

STUDYING ARCHAEOLOGICAL CAVE SITES AND SEDIMENTS

Cave sites remain the main source of archaeological information for the Pleistocene and early to middle Holocene periods in Southeast Asia. Hunters and gatherers used caves as intermittent camp sites during the Late Pleistocene, and increasing usage occurred for burial during the Holocene period, especially in the Neolithic and later (Anderson 1997, 2005; Barker et al. 2002, 2007). Archaeological work in cave sites normally focuses on the mouth or entrance and any contiguous rockshelters, with the assumption that only rarely did prehistoric people inhabit the deep and dark interior of caves, although they certainly visited these areas.

Caves, according to White (1988:60), are “natural openings in the earth.” There are different varieties of caves but this article is only concerned with karstic caves formed by dissolution of limestone through water action. “No two caves are exactly alike in their bedrock infrastructure, exposition, size, internal karstic relations, or influence of external geomorphological phenomena” (Farrand 2001:538). Many sediments inside caves in karst come from the weathering detritus of dissolving limestone both within and around the caves. This frequently includes quartz sand and chert nodules as well as clay minerals formed directly in the cave environment or transported into the cave by fluvial or aeolian processes (White 1988). Cave sediments also include organic sources, especially bird and bat guano, insect carapaces, and vertebrate remains. Many caves in Southeast Asia also contain substantial deposits of anthropogenic origin, particularly burials and a variety of occupation deposits. Anthropogenic contributions are varied and differ from site to site, and “can result from either intentional or unintentional human acts” (Farrand 2001:542; French 2003). Often found in caves are middens, formed primarily from food refuse, lithic debris from tool manufacture and discard, and ash and charcoal from hearths.

“Caves serve as traps for a variety of sedimentary types, and normally, whatever is deposited within a cave system remains there and is commonly modified and reworked in place” (Courty et al. 1989:194). In the tropical and subtropical regions there is enormous reworking of deposits through faunal and floral bioturbation, and through stream and mudflow processes, as well as substantial chemical diagenesis, particularly relating to the leaching and alteration of phosphates in various forms, and the leaching and precipitation of calcium carbonate, gypsum and iron.

A number of processes act on archaeological deposits in caves that can change, preserve, or destroy them. One of the most significant is chemical transformation, primarily caused by water that dissolves organic and inorganic materials (Karkanis et al. 2002:916). For instance, bat guano may be oxidized by water, causing it to break down into phosphates, which react with the carbonates present in the cave, including anthropogenic deposits such as wood ash, dissolving and/or replacing them. Bone in particular sees many strange alterations when deposited in phosphatic sediments, with the organic components often being completely destroyed or mineralized, in addition to alteration of the mineral components (Karkanis et al. 2000, 2002). In addition to dissolution and alteration, water action is ultimately responsible for cementation processes in limestone caves, through the precipitation of calcium carbonate and gypsum in particular, which can cement sediments, including archaeological materials, within various speleothem formations,

such as travertine. According to Anderson (1997:610), “among the more common difficulties encountered in cave archaeology in Southeast Asia is the carbonate cementing of the deposits associated with the formation of dripstones or percolation of calcareous ground water.”

The pH level of cave sediments can either enhance preservation of or destroy organic deposits, and this varies with time and localized processes such as guano deposition (Shahack-Gross et al. 2004) and diagenesis, carbonate formation, and deposition of archaeological materials. Charcoal tends to be resilient to biological decay and not strongly affected by the pH of the sediments (Balme and Beck 2002:159), although other archaeological materials, such as bone or wood ash are affected, and remains such as starch in sediments can be destroyed (*ibid.*:164).

There are various approaches to understanding site formation in cave contexts, in addition to interpretative stratigraphy carried out on site. The approach used here is soil micromorphology, seldom used until recently in Southeast Asia, which enables study of in situ site-specific cultural materials and sediments within a detailed stratigraphic and environmental framework. In this project the focus of soil micromorphological application was the better understanding of specific archaeological deposits, and no attempt was made to investigate the entirety of the suite of formation processes at either site, although additional approaches were carried out and are reported in Mijares (2005*a*).

The characterization of micro-indicators can enable identification of cultural activities not visible on a macroscopic scale, along with interpretation of complex contextual archaeological histories directly from the soil and sedimentary record. The soil micromorphology approach was first applied in the region at the Tingkayu site complex in Sabah (Magee 1988) and at Gua Gunung Runtuh (Zauyah 1994), both in Malaysia. Recently, the approach has been applied in Niah Cave, Malaysian Borneo (Lewis 2003, 2004; Stephens et al. 2005), and at Tabon and Ille Caves in Palawan, Southeast Philippines (Lewis 2004; 2007). The approach was also applied to a pre-shell midden deposit at the Nagsabaran site in the Cagayan Valley, Northeast Luzon, Philippines (Mijares 2005*b*). There are some comparative studies (Magee 1988; Stephens 2004), which have mainly focused on palaeo-environmental reconstruction, although discussion of indicators of human occupation of caves is also pursued.

Archaeological cave sediments have, however, seen a great deal of micromorphological study elsewhere, particularly in Europe, western Asia and North America (e.g., Courty et al. 1989; Goldberg 1979; Macphail and Goldberg 2003; Karkanas et al. 2000, 2002; Shahack-Gross et al. 2004). Through these investigations it is clear that one can expect to develop information about cultural use of space within the caves themselves, cave environmental history, and the wider cultural landscape, through study of cave and rockshelter deposits. In addition, cave deposits provide a great record of larger scale palaeoenvironmental history, and a number of direct dating opportunities (e.g., Bird et al. 2005, 2007), thus allowing links to be built between cultural landscapes, adaptation, and environment, with changes in these connections studied over time.

THE THIN-SECTION STUDY FROM THE PEÑABLANCA CAVE SITES

Samples for soil micromorphological study were selectively taken from the major deposits at Eme and Dalan Serkot Caves in the Peñablanca Municipality of the

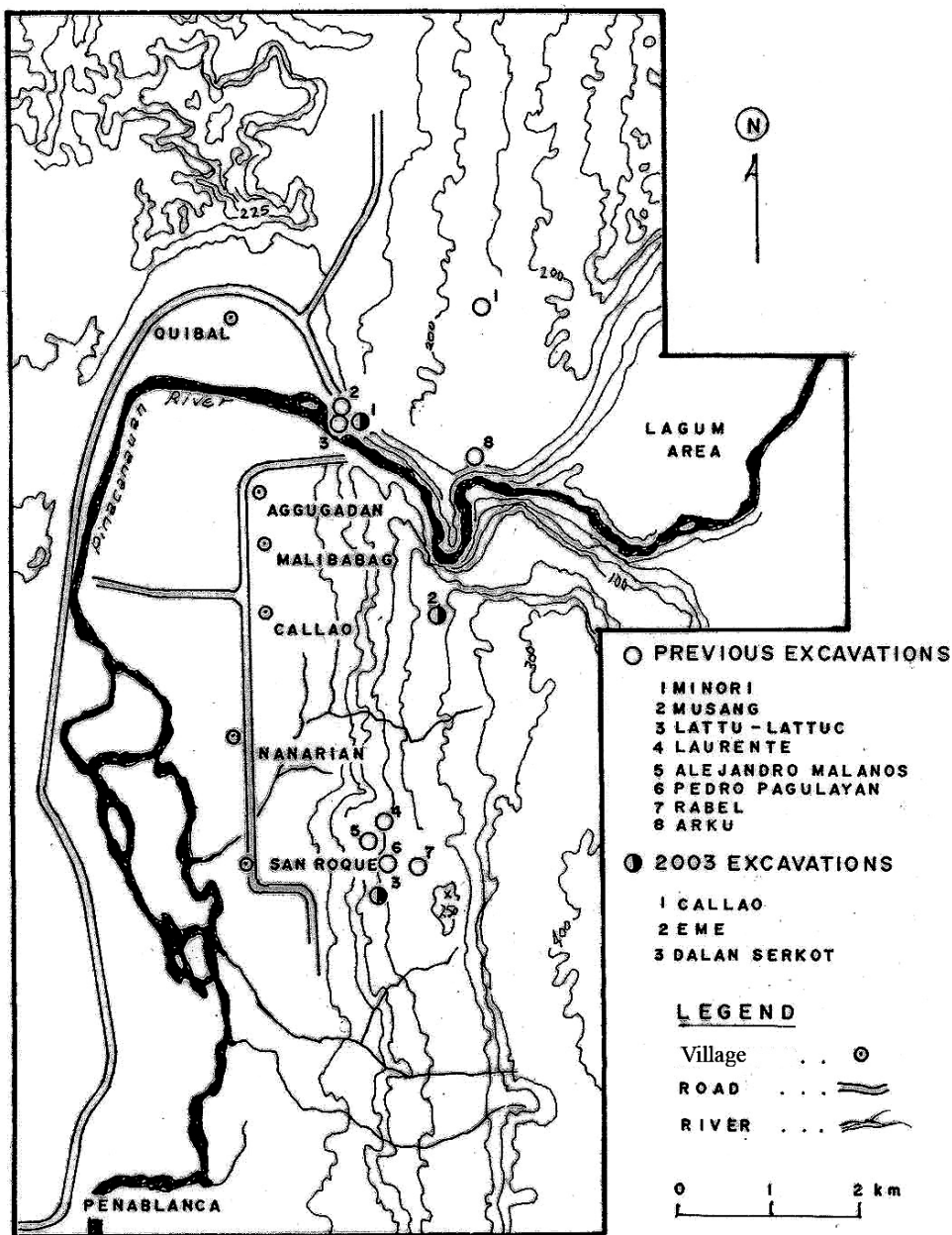


Fig. 2. Map showing locations of cave sites mentioned in the text in the Peñañlanca area of the Cagayan Valley (Mijares 2006).

Cagayan Valley (Fig. 2). Additional samples taken from a third cave, Callao, will be reported elsewhere (Mijares and Lewis in press). A full description of the Peñañlanca fieldwork, other post-excavation studies, and further interpretations based upon these can be found in Mijares (2005a, 2006).

TABLE I. QUALITATIVE DESCRIPTION OF SOIL MICROMORPHOLOGY FEATURES

SITE/SECTION	TEXTURE	C:F RATIO	MICROSTRUCTURE	GROUNDMASS	POROSITY
Eme 1	Silty clay (loam)	10:90	Crumbs	Stipple speckled	15%, ch, ch, po, pv
Eme 2	Silty clay (loam)	10:90	Granular	Stipple speckled	20%, ch, po
Dalan Serkot 1	Silty clay (loam)	15:75	Angular blocky	Stipple speckled	5%, ch, ch
Dalan Serkot 2	Clay sandy	7:93	Subangular blocky	Porostriated	5%, ch, ch

ch = channel
po = poroids
pv = packing void

Samples for this study were taken as blocks, which were air dried, then impregnated with crystic resin and hardened to form solid blocks from which slices were cut ($4 \times 6 \times 0.8$ cm), mounted on glass slides, and ground to produce 2.5 mm-thick thin sections. These provide a long-lasting record of in situ archaeological deposits within a contextual framework. Soil thin sections were analyzed using a petrographic (polarizing) Leica microscope at several magnifications (from macroscopic through all microscopic levels), and under both plane polarized (PPL) and crossed polarized light (XPL), with a focus on studying processes of context formation and the alteration, patterning, and identification of materials. All percentages mentioned are based on visual estimates of area.

The thin sections for this project were made by Tony Phimphisane at the Earth and Marine Sciences Department of the Australian National University (ANU). Analysis was carried out by the authors at that department, and at the Research School of Pacific and Asian Studies (ANU Canberra), following the guidelines of Bullock et al. (1985), with consultation of Stoops (2003) and Courty et al. (1989). The general descriptions are given below while the qualitative and semi-quantitative descriptions of the groundmass, mineral and organic components, and pedofeatures are found in Tables 1 and 2. The detailed descriptions are presented in Mijares (2006).

The description of an oriented soil sample in thin section can be divided into four main components: micro-structure, mineral and organic components, groundmass, and pedofeatures. Structure refers to the size, shape, and arrangement of particles and voids in aggregates and non-aggregates. Mineral and organic components are identified in relation to their sizes and estimated percentage of visual area. Groundmass is described based on the coarse/fine (c:f) grain-size ratio, texture, birefringence properties, and type of fabric. Pedofeatures are “discrete fabric units present in soil materials recognizable from an adjacent material by difference in concentration in one or more components . . . or by difference in internal fabric” (Bullock et al. 1985:19).

Eme Cave: Description of Samples

The Eme Cave complex lies about 2 km southwest of the National Museum of the Philippines Field Station at Callao Resort. The cave complex was first discov-

ered during the 1977 archaeological survey headed by Wilfredo P. Ronquillo and Rey Santiago (1977) of the National Museum. It is composed of three caves under a good forest cover. The GPS coordinates are 121°49.71' E, 17°41.25' N, and the complex lies at an elevation of 220 m above mean sea level. Two 2 × 1 m squares were laid out as shown in Figure 3, and subsequently excavated. The northern square was designated SQ 1 and the southern SQ 2. The excavation

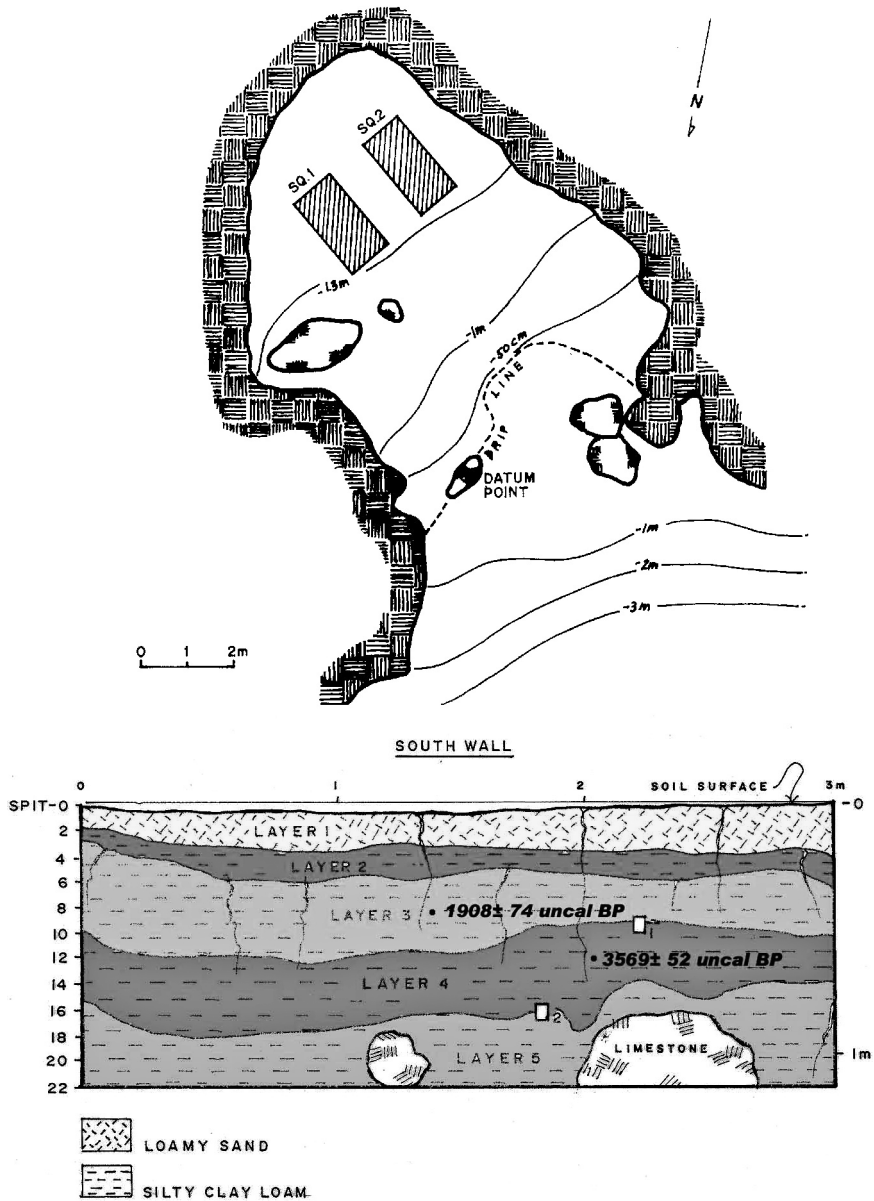


Fig. 3. Diagram of the Eme Cave excavation and section of the south wall of Square 2, showing the locations of samples (white boxes) (Mijares 2006).

area is in the back of the cave, and generally flat, but the entrance of the cave along the drip line is a mound formed from fallen limestone blocks and washed-in sediments.

The excavation of Eme Cave revealed a massive sedimentary deposit with stratigraphic boundaries difficult to delineate, but noted by slight color variation in the field. The sediments are homogeneous silty clay loam. The profile showed strong and deep cracking through wet-dry processes, leading to some doubt regarding the integrity of artifact contexts. Two samples were analyzed from Eme Cave, taken from the southern wall of SQ 2 in the excavations, in locations avoiding obvious cracks (see Mijares 2005a).

The Eme 1 thin section showed two layers, the upper 4 cm—Layer 3—consisting of a very porous deposit (10–20% porosity, mostly packing pores), and the lower 2 cm of a denser deposit (5–15% porosity, mostly channels)—Layer 4. Layer 3 is thought to be late Neolithic based on finds, although it is dated to 60 B.C.–A.D. 260 on charcoal (Mijares 2005a), while Layer 4 appears to date to the end of the pre-ceramic period on finds, from 2040–1740 B.C. (*ibid.*). The general color for both is yellowish brown (PPL and XPL), with a stipple speckled groundmass, apparently composed mainly of mineral sediment (clay, silt, and sand) with only a small guano component, and both have moderately sorted rounded to subrounded aggregates and rock fragments. Both layers have moderately developed crumb (100–500 μm) structure with rounded micro-aggregates, and circular poroids about 2–4 mm wide, possibly due to faunal activity (Fig. 4). These are continuously filled by loose crumbs and subrounded micro-aggregates and rock fragments.

There are bone fragments (5%) from 500 μm to a maximum of 8 mm in size. Minerals identified include rounded to subrounded quartz, 30–500 μm in size, plagioclase (200–350 μm), olivine (100–200 μm), pyroxene (50–350 μm), and amphibole (150–300 μm). There is an estimated 5–10 percent organic materials in both layers, including plant residues 1000–2000 μm in size, plant roots, and pollen grains (unidentified) about 2000 μm in diameter. A plant residue with its structure still intact, probably of wood, was observed in the lower section. Charcoal fragments about 500–1000 μm in size were observed covering 5 percent of the area of the slide.

There are three fabric pedofeatures dispersed throughout the section. The first are dark aggregates about 1000–5000 μm in size. These are dark red to black in PPL and XPL with low birefringence. They cover about 10 percent of the area of the section, and appear to be burnt or otherwise oxidized versions of the main sediment. The second fabric pedofeature type is orange brown in PPL and pale orange brown in XPL, with high birefringence. The fabric is dusty reddish clay with 50–500 μm mineral inclusions of quartz and plagioclase with micro-cracking, and may represent oxidized clay from a limestone weathering horizon either inside or outside the cave. Both of these pedofeature types appear as rounded aggregates, and are obviously mechanically transported; the latter type has been found commonly in other limestone caves in the region microscopically (e.g., Lewis 2007); the former is thought to represent locally transported archaeological deposits. The third pedofeature type is subrounded nodules with a fabric similar to the matrix, but strongly impregnated with oxidized iron. The sizes range from 1000–1500 μm . These appear to be related to rooting and oxidation

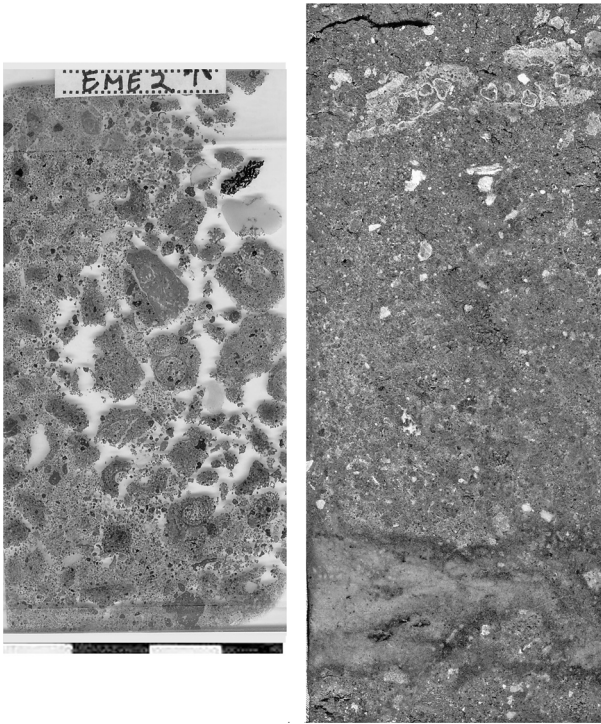


Fig. 4. Macroscopic scanned images of Eme sample 2 (left) and Dalan Serkot sample 2 (right) thin sections.

of the cave sediments. Textural pedofeatures seen include typical coatings of micrite, along with impregnative coatings of clay and micrite, around most aggregates and rock fragments. These are related to precipitation of calcium carbonate, along with illuviation of clay leached from elsewhere in the profile. Microsparite crystals also fill voids and connect peds and grains.

The Eme 2 sample was taken at the boundary of Layers 4 and 5. Layer 4 has been described above; Layer 5 is similar, but with a brown color, and had no cultural materials reported from the field. The thin section does not show distinct layers. The sediment color is brown (PPL) to strong brown (XPL) and is silty clay loam, with subangular to subrounded aggregates (2–7 mm) separated by faunal channels 4 mm wide. The thin section has a moderately developed crumb to granular structure. There are subrounded to rounded aggregates 40–60 μm and crumbs 20–40 μm in size, with a porosity of 20 percent; most aggregates have intrapedal cracks. The circular poroids have loose continuous infilling of crumbs, granules, and rock fragments.

Subrounded to subangular quartz grains 200–800 μm in size dominate the mineral content. Limestone fragments are subrounded and 30–7000 μm in size. Spherical radiolarian chert, about 1000 μm in size, was also identified. Other minerals are calcite grains (2000 μm), biotite (200–300 μm), olivine (100–350 μm), amphibole (300–500 μm), and plagioclase (100–600 μm). There are also 1200–2000 μm bone fragments. Plant residues (300–400 μm) with their structure still recognizable were observed. Charcoal 200–500 μm in size can be seen across

the section covering 2 percent of the area. Remains of partially decomposed roots were also identified.

An earthenware fragment was found in the thin section. It is black in PPL and dark red-black in XPL. It contains sand grains of quartz (200–750 μm), pyroxene (400 μm), biotite (400 μm), and muscovite (300 μm). It has vughy and channel voids. A round calcareous wood ash aggregate (9 mm), pinkish gray in PPL and gray in XPL, was observed in the upper part of the thin section. Another fabric pedofeature in this thin section is a zone of red orange (PPL) and red brown (XPL) very fine clay matrix with micro-cracking. It has 50 μm quartz inclusions. Additional pedofeatures include a calcite coating 300–500 μm thick on one of the aggregates. Coatings of clay and micrite, as described for Eme 1, can be seen on bone fragments, and pseudomorphic calcite crystals partially impregnate some bones. Subrounded oxidized iron nodules are frequently found in the matrix, about 30–40 μm in size. Finally, rounded yellow orange (PPL) and reddish brown (XPL) excrements 100 μm in size were observed infilling channels.

DALAN SERKOT CAVE: DESCRIPTION OF SAMPLES

Dalan Serkot Cave is located in the village of San Roque, south of the local National Museum Field Station. The cave has coordinates of 17°39.87' N, 121°49.20' E, and an elevation of 165 m above mean sea level. The mouth of the cave faces southeast. The cave has a single passage and contains two narrow chambers. The entrance floor slopes into the cave at a 30° inclination. Two squares were opened: SQ 1 (2 × 2 m) on the east side near the entrance, and SQ 2 (1 × 2 m) on the west side and farther inside the cave. The sediment profile of Dalan Serkot was a homogeneous silty clay loam to clay loam sediment. Two thin-section samples were taken from the western wall of SQ 1 (see Fig. 5) (Mijares 2005a).

Dalan Serkot 1 was taken at the transition from a primarily ceramic assemblage (Layer 1) to a lower lithic assemblage (Layer 2). These layers are distinguished archaeologically, although they are very similar to each other sedimentologically, but with Layer 2 more clayey than the loamy Layer 1. Layer 1 was radiocarbon dated to 1950–1740 B.C. on charcoal (Mijares 2005a), and was associated with potsherds, human teeth and phalanges, faunal remains, and a few flake tools. Layer 2, on the other hand, has primarily a flake tool assemblage with few faunal remains, and was radiocarbon dated on charcoal to 5310–5040 B.C. (ibid.). The thin section viewed macroscopically has a massive structure with a large void in the upper left margin. The sediment color is yellowish red (PPL and XPL), and again is primarily mineral, with the main sediment fabric dominated by clay (vs. guano). No distinction could be made between the layers in thin section.

The sample has a well-developed angular blocky structure, with intrapedal cracks and channels. Channels are partially filled with silty clay and micrite. Porosity is estimated at 5 percent. Limestone fragments (600 μm –4 mm) and quartz grains (50–1500 μm), both subrounded to round and subangular in shape are abundant in the thin section. Other minerals identified are amphibole (60–600 μm), biotite (100 μm), pyroxene (200–350 μm), calcite (1000 μm), and radiolarian chert (350–500 μm). Bones (350 μm –5 mm) and shells (8 mm) were observed across the thin section. Charcoal fragments (700–1000 μm) are relatively abundant, estimated at 7 percent of the visible area. “Punctuations” are evenly distributed.

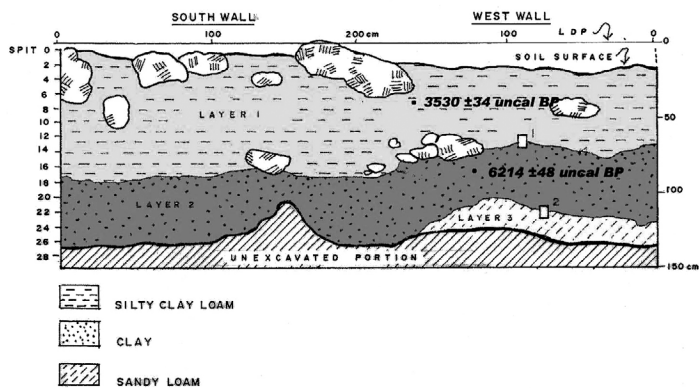
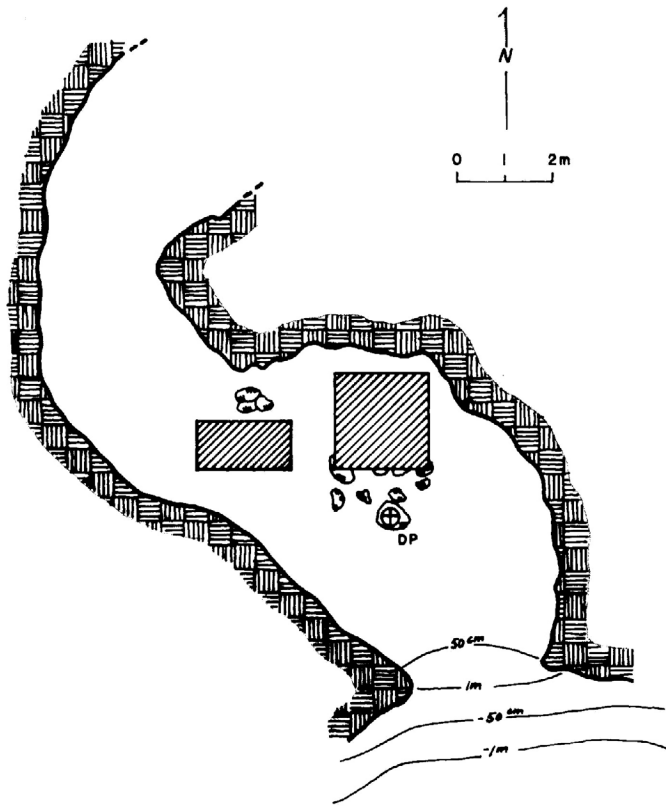


Fig. 5. Diagram of the Dalan Serkot Cave excavation and section of the south and west wall of Square 1, showing the locations of samples (white boxes).

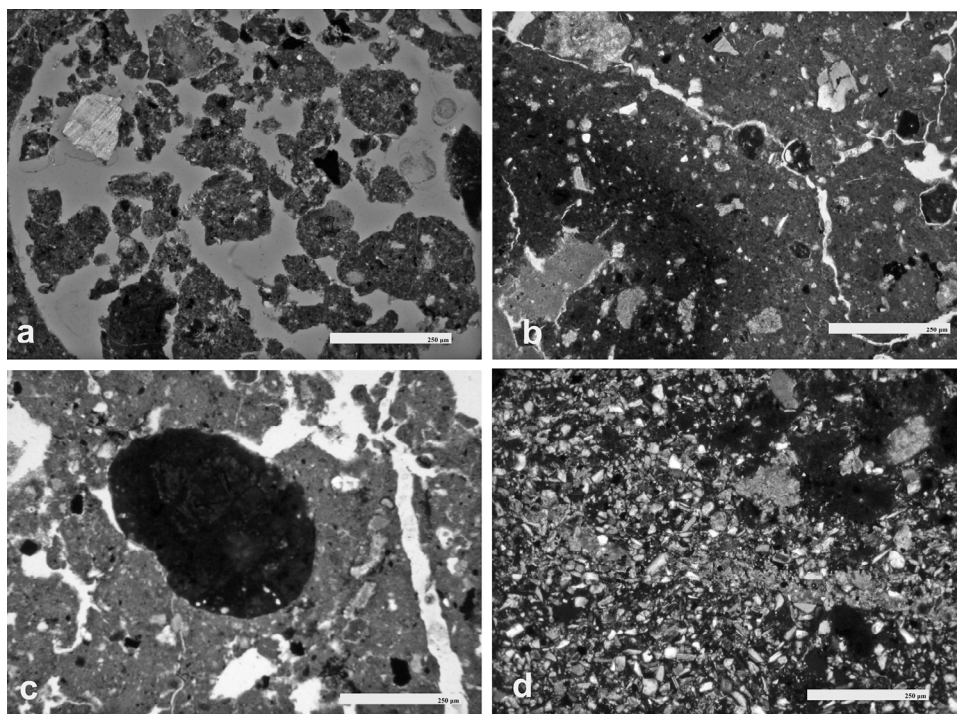


Fig. 6. a. Faunal activity forming poroids with infilling (Eme 1-PPL); b. Highly oxidized ped with micro cracking possibly due to burning (Eme 1-PPL); c. Dark red dirty clay (Dalan Serkot 1-PPL); d. Volcanic ash (Dalan Serkot 2-XPL).

There are two fabric pedofeatures identified in the thin section. The first are zones of reddish black (PPL) and opaque (XPL) fine-grained matrix with accommodated cracks, and inclusions of quartz and amphibole. The second type is aggregates of dark red (PPL), “dirty” red (XPL) clay (255–850 μm) (Fig. 6), again possibly originating and mechanically transported from weathering of limestone sediments or soils nearby. The widespread and apparently constant occurrence of such aggregates, mentioned above, suggests their deposition is an ongoing long-term process. Other pedofeatures include micrite coatings of channel walls related to the precipitation of calcium carbonate from water in the cave, and coatings of illuviated clay and precipitated micrite mixed together on grains and nodules, as described at Eme, as well as calcitic hypocoatings of voids. Some channels are partially infilled with silty clay. Some of the bones are partially or completely replaced with pseudomorphic sparite crystals. In addition, rounded iron oxide nodules that are reddish black to black in PPL and opaque in XPL (100–350 μm) are seen, and some of the groundmass is relatively depleted of iron and has a yellowish color in PPL. These zones have diffuse boundaries with the main adjacent reddish brown matrix. Finally, reddish yellow (PPL and XPL) faunal excrement was seen in one channel, consisting of “cylinders” with rounded ends (1200 μm), circular (255–340 μm) in cross section.

The Dalan Serkot 2 sample was taken at the boundary of Layer 2 (described above) and Layer 3 (Fig. 4). Layer 3 is devoid of cultural remains and was

identified as travertine in the field, although the thin section described below shows that this was not entirely the case. In thin section, the lower part of Layer 2 was similar to its upper reaches described above. The layer is a fairly massive matrix-supported reddish brown clay deposit, but with a 2-mm thick layer of calcium carbonate extending across part of the thin section, overlying a mixed layer, 7 mm thick, of the main deposit with calcium carbonate deposits. In this layer, limestone rock fragments are macroscopically visible (2–5 mm). Quartz grains, which are rounded to subrounded, dominate the coarse fraction (50–900 μm). Other minerals identified are pyroxene (50–450 μm), amphibole (200–450 μm), muscovite (500 μm), plagioclase (50–450 μm), and calcite (170–2000 μm). Only one bone (500 μm) was observed in the entire thin section. Typical clay coatings of grains and aggregates are seen, along with cap-linking coatings of aggregates and infilling of channels 85–170 μm thick by sparite. The latter are also seen in the lower parts of the thin section.

Below this “travertine” layer we identified an intact volcanic ash deposit in thin section, which, although slightly disturbed at its upper boundary, is well sorted by grain size. The volcanic ash crystals (pyroxene, amphibole, and plagioclase were identified), along with other grains, such as quartz, are subangular in shape, relatively fresh, and have not been exposed to much disturbance or weathering (Andrew Christy 2004, pers. comm.), despite being obviously size sorted. The texture of this deposit is a sandy loam with a c:f ratio of 10:90.

DISCUSSION

Understanding the intricate details of the processes that form archaeological sites is an important component in interpreting past cultures. Site formation includes the discernment of depositional and post-depositional processes, which include sedimentary, biogenic, and anthropogenic agents. Analysis of undisturbed soil samples in thin section provides the high resolution needed to explore such processes. This approach was used in the analysis of site formation in cave sites from Peñablanca, northern Luzon, and complements other approaches to understanding human activities there during the mid-Holocene period.

Much of what was learned through soil micromorphological study was not unexpected in relation to the excavation findings. For instance, at Eme it was clear in thin section that there was substantial disturbance through bioturbation, and although there was no clear sign of the influence of the shrink-swell cracking seen in the field in the samples, it is likely that the microscopic cultural materials found in “non-cultural” Layer 5 (wood ash, possible burnt soil fragments, pottery) were transported from the overlying layers.

However, it has been possible to further characterize the cultural deposits at the caves, as well as to add information regarding the preservation and integrity of deposits. The sediments from these caves generally derive from a number of sources. As with many such cave sites, the entrances of Eme and Dalan Serkot have rock and soil mounds due to roof fall. Inside the caves there are pebble- to boulder-sized limestone pieces from the roof that litter the floors and occur throughout the accumulated sediments. The weathering of the cave structure, along with in situ weathering of fallen rocks and speleothems evidently contributes to the general clayey matrices of the sites, as well as to the number of inclu-

sions of chert and quartz, and to the generally calcareous nature of the sediments and many pedofeatures. An additional clay source seen in both caves and in caves elsewhere in the region (Lewis 2003, 2007) appears as rounded or subrounded aggregates of orange-red clay, which are found throughout the matrices and within speleothem deposits. These appear to be regularly and constantly mechanically transported into cave deposits, either from eroding soils or sediments outside the caves, or eroding clay deposits within the caves. The calcium carbonate precipitation features seen throughout the deposits also appear to be regularly forming, and presumably have continued to do so since sedimentation began inside the caves.

No gypsum formations or other authigenic silt/sand crystals were noted in these caves, although they are known from other sites in the region, particularly sites with a long history of guano deposition (e.g., Niah Cave: Barker et al. 2002, 2007; Tabon Cave: Lewis 2007; Lewis et al. 2008). Other post-depositional processes noted in the sediments from both caves were some clay illuviation in pores or on aggregates (but with no instances of clear sequences of coatings), and iron oxide precipitation both in nodules and as staining on the main fine fabrics. As with the processes mentioned above, these appear to be ongoing and long-term, and all are expected to be seen in tropical and subtropical karst environments, reflecting frequent wetting, leaching, and drying of the sediments.

Guano was not clearly expressed in the thin sections studied, either as amorphous phosphatic inclusions or proxy indicators (authigenic phosphate minerals, bones with replacement by phosphates, etc.), as seen elsewhere (e.g., Karkanis et al. 2000, 2002; Lewis 2007; Shiegl et al. 1996; Weiner et al. 2002). Although both caves do contain guano today, and this was presumably a major contributing sediment source in the past, some combination of reworking by soil fauna and roots, leaching and oxidation of the sediments, localized hydrology, geochemistry, and sediment type input must be involved in effectively erasing the optically visible guano signature from the Eme and Dalan Serkot samples.

Anthropogenic deposits include artifacts such as small earthenware sherds and transported micro-traces of burning features. The wood ash fragment, along with the reddish black to reddish orange fragment described above may represent sediments from a fireplace. Stephens and colleagues (2005:48) discuss one possible process for the reddening of the sediment as a result of burning (oxidation), especially with the presence of charcoal. There is a comparatively large amount of charcoal visible in layers known to have been used by humans (5–20% of visible area), as compared to layers with culturally sterile deposits in the field (about 2%).

In summary, the Eme Cave samples appear to reveal continuity in occupation from the latest pre-ceramic through to later ceramic periods. However, the deposits are seriously disturbed by faunal turbation and shrink-swell processes, with evidence for later cultural materials being mixed down into the earlier horizons. The extent of this disturbance is unclear, but it has definitely affected fine fragments of pottery and charred plant remains. Remains of hearth deposits found in the thin sections attest to localized occupation activities, at least on a short-term basis, but the stratigraphic integrity of the deposits studied is questionable.

At Dalan Serkot, thin-section study was not particularly informative regarding site occupation or preservation, but charcoal possibly related to human burning activities was identified. However, at this cave an intact layer of volcanic ash was

discovered through thin-section interpretation, and existing radiocarbon dates suggest it was deposited before 6200 B.P. (Mijares 2006). This would represent an eruption, probably from one of the local volcanoes, during a time when people are certain to have been living in the area. A volcanic ash deposit was also observed at nearby Pedro Pagulayan Cave, where Wasson and Cochrane note that “the sandy deposit in the Pedro Pagulayan Cave is a volcanic ash or tephra of andesitic composition” (1979:21). As at Dalan Serkot, where size sorting of grains suggests some minor degree of movement by water, they also suggest that the volcanic ash was washed into the cave, forming a significant source of sediment deposition.

What impact did these, or other eruptions, have on ancient Cagayan Valley communities? Directly dating the ash from Dalan Serkot, as well as conducting geochemical analysis on it, will be important for future research. This volcanic ash layer could be used as a marker for other cave sites in Peñablanca. The immediate region is not well known regarding tephrochronology or the histories of individual volcanoes, and it would be very interesting to develop an interdisciplinary study looking at tephtras in the area. Building up a better understanding of the relatively recent volcanic history of the region could produce local absolutely dated temporal sequences that would be useful to archaeologists, as well as important information regarding the prehistoric landscape.

The identification of the white volcanic ash as travertine in the field has echoes with other projects in the region; for instance a hard travertine interpreted as a marker horizon at Tabon Cave in Palawan (Fox 1970) has since been demonstrated to have surface layers (at least) composed primarily of gypsum (Lewis et al. 2008), and many small white travertine layers identified by Lewis in the field within guano deposits in the same cave are also non-calcareous, and have optical qualities similar to gypsum (Lewis 2007). It seems clear that speleothem layers in soft sediments in archaeological cave sites should see laboratory assessment before being labelled as calcareous.

CONCLUSIONS

This study of Cagayan Valley caves, in conjunction with work in the southern Philippine Islands, marks a major, systematic suite of micromorphological investigations of cultural cave deposits in the region, in comparison to a number of complimentary excavation and post-excavation approaches. Through soil micromorphology it has been possible to characterize further the cultural deposits in the caves, as well as to add information regarding the preservation and integrity of the deposits. In this regard, work in the Cagayan Valley is especially significant since, unlike in much of the south, there are known contemporaneous prehistoric open-air occupation and ancient land use sites in the region. This means that it will be possible to develop landscape archaeology approaches more easily here compared to the southern tropical islands, where much work is needed to simply locate occupation sites that are not in caves. It is hoped that these thin sections will contribute substantially to the application of soil micromorphology to archaeology in the Southeast Asian region, and will encourage further detailed work on cave site occupation and, possibly more significantly, on nearby open-air sites where these are found.

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REFERENCES

- ANDERSON, D.
 1997 Cave archaeology in Southeast Asia. *Geoarchaeology* 12(6):607–638.
 2005 The use of caves in Peninsular Thailand in the late Pleistocene and early and middle Holocene. *Asian Perspectives* 44(1):137–153.
- AOYAGI, Y., M. AGUILERA, H. OGAWA, AND K. TANAKA
 1993 Excavation of hill top site, Magapit Shell Midden in Lal-lo Shell Middens, Northern Luzon, Philippines. *Man and Culture in Oceania* 9:127–155.
- BALME, J., AND W. BECK
 2002 Starch and charcoal: Useful measures of activity areas in archaeological rockshelters. *Journal of Archaeological Science* (29):157–166.
- BARKER, G., H. BARTON, P. BEAVIT, M. BIRD, P. DALY, C. DOHERTY, D. GILBERTSON, C. HUNT, J. KRIGBAUM, H. LEWIS, J. MANSER, S. MCCLAREN, V. PAZ, P. PIPPER, B. PYATT, R. RABETT, T.E.G. REYNOLDS, J. ROSE, G. RUSHWORTH, AND M. STEPHENS
 2002 Prehistoric foragers and farmers in South-East Asia: Renewed investigation at Niah Cave, Sarawak. *Proceedings of the Prehistory Society* 68:147–164.
- BARKER, G., H. BARTON, M. BIRD, P. DALY, I. DATAN, A. DYKES, L. FARR, D. GILBERTSON, B. HARRISSON, C. HUNT, T. HIGHAM, L. KEALHOFER, J. KRIGBAUM, H. LEWIS, S. MCCLAREN, V. PAZ, A. PIKE, P. PIPPER, B. PYATT, R. RABETT, T. REYNOLDS, J. ROSE, G. RUSHWORTH, M. STEPHENS, C. STRINGER, J. THOMPSON, AND C. TURNEY
 2007 The “human revolution” in lowland tropical Southeast Asia: The antiquity and behavior of anatomically modern humans at Niah Cave (Sarawak, Borneo). *Journal of Human Evolution* 52:243–261.
- BELLWOOD, P.
 1997 *Prehistory of the Indo-Malaysian Archipelago*. 2nd ed. Honolulu: University of Hawai'i Press.
 2004 Colin Renfrew's emerging synthesis: Farming, languages and genes as viewed from the antipodes. In *Traces of Ancestry: Studies in Honour of Colin Renfrew*: 31–39, ed. M. Jones. McDonald Institute. Cambridge: Cambridge University Press.
- BIRD, M. I., E. BOOBYER, C. BRYANT, H. LEWIS, V. PAZ, AND W. E. STEPHENS
 2007 A long record of environmental change from bat guano deposits in Makangit Cave, Palawan, Philippines. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 98:59–69.

- BIRD, M. I., I. D. TAYLOR, AND C. HUNT
 2005 Palaeoenvironments of insular Southeast Asia during the last glacial period: A savannah corridor in Sundaland? *Quaternary Science Reviews* 24:2228–2242.
- BULLOCK, P., N. FEDEROFF, A. JONGERIUS, G. STOOPS, AND T. TURSINA
 1985 *Handbook for Soil Thin Section Description*. Waine Resesearch Publications, Wolverhampton.
- COURTY, M. A., P. GOLDBERG, AND R. MACPHAIL
 1989 *Soils and Micromorphology in Archaeology*. Cambridge: Cambridge University Press.
- CUEVAS, M.
 1980 Preliminary report on the archaeological excavation conducted at Callao Caves. *Manuscript of the National Museum, Manila*.
- DIZON, E.
 2003 New direct dating of human fossils from Tabon Cave, Palawan, Philippines. *Proceedings of the Society of Philippine Archaeologists* 1:63–67.
- DURKEE, E., AND S. PEDERSON
 1961 Geology of northern Luzon. *American Association Petroleum Geologists Bulletin* 45:137–168.
- FARRAND, W.
 2001 Sediments and stratigraphy in rockshelters and caves: A personal perspective on principles and pragmatics. *Geoarchaeology* 16:537–557.
- FOX, R.
 1970 *The Tabon Caves*. Monograph of the National Museum No. 1, Manila.
- FOX, R., AND J. PERALTA
 1974 Preliminary report on the Paleolithic archaeology of Cagayan Valley, Philippines, and the Cabalwanian industry. Paper presented at the First Regional Seminar on Southeast Asian Prehistory and Archaeology, Manila.
- FRENCH, C.
 2003 *Geoarchaeology in Action: Studies in Soil Micromorphology and Landscape Evolution*. London: Routledge.
- GOLDBERG, P.
 1979 Micromorphology of sediments from Hayonim Cave, Israel. *Catena* 6:167–181.
- HENSON, F.
 1977 The Laurente Cave archaeological project: A preliminary report. *Manuscript of the National Museum, Manila*.
- HUNG, H. C.
 2004 Neolithic interaction between Taiwan and Northern Luzon: The pottery and jade evidence from Cagayan Valley. *Manuscript of ANH-RSPAS-ANU, Canberra*.
- KARKANAS, P., O. BAR-YOSEF, P. GOLDBERG, AND S. WEINER
 2000 Diagenesis in prehistoric caves: The use of minerals that form *in situ* to assess the completeness of the archaeological record. *Journal of Archaeological Science* 27:915–929.
- KARKANAS, P., J.-P. RIGAUD, J. F. SIMEK, R. M. ALBERT, AND S. WEINER.
 2002 Ash, bones and guano: A study of the minerals and phytoliths in the sediments of Grotte XVI, Dordogne, France. *Journal of Archaeological Science* 29:721–732.
- LEWIS, H.
 2003 The potential of soil micromorphology in Southeast Asian archaeology: Preliminary work at Niah Cave Sarawak, Malaysia, and Ille Cave, Palawan, Philippines. *Hukay. Journal of the University of the Philippines Archaeological Studies Program* 5:60–72.
 2004 The soil micromorphological potential of cultural sediments from cave sites in Island Southeast Asia: Progress report on work at Niah, Ille and Tabon caves. Unpublished report for the Evans Fund, the Society of Southeast Asian Studies, and the Niah Cave Project (AHRB).
 2007 Preliminary soil micromorphology studies of landscape and occupation history at Tabon Cave, Palawan, Philippines. *Geoarchaeology* 22(7):685–708.
- LEWIS, H., K. JOHNSON, AND W. RONQUILLO
 2008 Preliminary results of speleothem dating from Tabon Cave, Palawan, Philippines: Moisture increase at the last glacial maximum? *Hukay. Journal of the University of the Philippines Archaeological Studies Program*.

- MACPHAIL, R., AND P. GOLDBERG
 2003 Gough's Cave, Cheddar, Somerset: Microstratigraphy of the late Pleistocene/earliest Holocene sediments. *Bulletin of Natural History Museum, London (Geol.)* 58:51–58.
- MAGEE, J.
 1988 Chapter 2: Oriented soil samples from Tingkayu Basin, in *Archaeological Research in South-eastern Sabah*. *Sabah Museum Monograph* 2:31–37, ed. P. Bellwood. Sabah Museum and State Archives, Kota Kinabalu.
- MATHISEN, M. E.
 1980 Plio-Pleistocene Geology of Central Cagayan Valley, Northern Luzon Philippines. Ph.D. diss., Iowa State University.
- MATHISEN, M. E., AND C. F. VONDRA
 1983 The fluvial and pyroclastic deposits of Cagayan Basin, Northern Luzon, Philippines—An example of non-marine volcanoclastic sedimentation in an interarc basin. *Sedimentology* 30:369–392.
- MIJARES, A. S.
 2001 An expedient lithic technology in Northern Luzon, Philippines. *Lithic Technology* 26(2): 138–152.
 2002 *The Minori Cave Expedient Lithic Technology*. Quezon City: University of the Philippines Press.
 2005a The archaeology of Peñablanca Cave sites, Northern Luzon, Philippines. *Journal of Austro-nesian Studies* 1(2):65–92.
 2005b The Nagsabaran shell midden site: A soil micromorphology approach. *Hukay* 8:1–12.
 2006 Unraveling Prehistory: The Archaeology of Northeast Luzon. Ph.D. thesis, Australian National University, Canberra.
- MIJARES, A., AND H. LEWIS
 in press Understanding Callao Cave site formation: A soil micromorphology approach.
- OGAWA, H., ED.
 2002 *Archaeological Research on the Lower Cagayan River—Study on the Historical Process of Hunter-Gatherer/Farmer Interdependent Relationship*. Report for the Grant-in-Aid for International Scientific Research (Field Research). Tokyo: The Ministry of Education, Science, Sports and Culture.
- REYNOLDS, T.E.G.
 1993 Problems in the Stone Age of South-East Asia. *Proceedings of the Prehistory Society* 59:1–15.
- RONQUILLO, W.
 1981 The technological and functional analysis of lithic flake tools from Rabel Cave, Northern Luzon Philippines 13. Anthropological Papers No. 13. Manila: National Museum of the Philippines.
- RONQUILLO, W., AND R. SANTIAGO
 1977 Archaeological caves and open sites exploration at Penablanca, Cagayan Province. *Manuscript of the National Museum, Manila*.
- SHAHACK-GROSS, R., F. BERNA, K. PANAGIOTIS, AND S. WEINER
 2004 Bat guano and preservation of archaeological remains in cave sites. *Journal of Archaeological Science* 31:1259–1272.
- SHIEGL, S., P. GOLDBERG, O. BAR-YOSEF, AND S. WEINER.
 1996 Ash deposits in Hayonim and Kebara Caves, Israel: Macroscopic, microscopic and mineralogical observations, and their archaeological implications. *Journal of Archaeological Science* 10:763–781.
- SHUTLER, R., AND M. E. MATHISEN
 1979 Pleistocene studies in the Cagayan Valley of Northern Luzon, Philippines. *Journal of the Hongkong Archaeological Society* 8:105–114.
- SNOW, B. E., R. SHUTLER, D. E. NELSON, J. S. VOGEL, AND J. R. SOUTHON
 1986 Evidence of rice cultivation in the Philippines. *Philippine Quarterly of Culture and Society* 14:3–11.
- STEPHENS, M.
 2004 Reconstructing Late Quarternary Paleoenvironments from deposits in the West Mouth of the Great Cave of Niah, Sarawak, Borneo. Unpublished Ph.D. thesis, University of London.

- STEPHENS, M., J. ROSE, D. GILBERTSON, AND M. CANTI
 2005 Micromorphology of cave sediments in the humid tropics: Niah Cave, Sarawak. *Asian Perspectives* 44(1):42–55.
- STOOPS, G.
 2003 *Guidelines for the Analysis and Description of Soil and Regolith Thin Section*. Soil Science Society of America, Inc., Wisconsin.
- THIEL, B.
 1980 Subsistence Change and Continuity in Southeast Asian Prehistory. Ph.D. diss., University of Illinois at Urbana-Champaign.
 1987 Excavation at Arku Cave, Northeastern Luzon Philippines. *Asian Perspectives* 21(2):229–264.
 1989 Excavation at Musang Cave, Northeastern Luzon, Philippines. *Asian Perspectives* 28(1):61–81.
- TSANG, C.-H., AND R. SANTIAGO
 2001 Recent archaeological studies in Northern Luzon and their implication for the prehistoric relationship between Taiwan and the Philippines. Paper presented at the International Conference on Austronesian Cultures: Issues relating to Taiwan, Taipei.
- WASSON, R., AND R. COCHRANE
 1979 Geological and geomorphological perspectives on archaeological sites in the Cagayan Valley, Northern Luzon, Philippines. *Modern Quaternary Research in Southeast Asia* 5:1–26.
- WEINER, S., P. GOLDBERG, AND O. BAR-YOSEF
 2002 Three-dimensional distribution of minerals in the sediments of Hayonim Cave, Israel: Diagenetic processes and archaeological implications. *Journal of Archaeological Science* 29:1289–1308.
- WHITE, W. B.
 1988 *Geomorphology and Hydrology of Karst Terrain*. Oxford: Oxford University Press.
- ZAUYAH, S.
 1994 Characteristic of soil layers in Gua Gunung Runtuh, in *The Excavation of Gua Gunung Runtuh and the Discovery of the Perak Main in Malaysia*: 123–140, ed. Z. Majid. Department of Museums and Antiquity Malaysia, Kuala Lumpur.

ABSTRACT

Soil micromorphology was among the approaches used to explore site formation in two cave sites in northern Luzon: Eme and Dalan Serkot Caves. Interplay of biogenic, sedimentary, and anthropogenic processes worked and reworked the archaeological sediments at both sites. Eme Cave was found to be highly bioturbated by faunal activities and shrink-swell processes, and caution is needed in interpreting its archaeological contexts. However, thin section study revealed wood ash and possible burnt soil fragments, along with charcoal, attesting to later prehistoric burning activity at the site at some time. In Dalan Serkot Cave, along with standard cave sediments a volcanic ash deposit was identified, apparently deposited before 6200 B.P., that must have affected local communities, and that could be used as a stratigraphic marker for future research in the area. **KEYWORDS:** Soil micromorphology, northern Luzon, Palaeolithic, Neolithic, cave sites.