Adaptation and foraging from the Terminal Pleistocene to the Early Holocene: Excavation at Bubog on Ilin Island, Philippines

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The recently discovered human remains from Callao Cave, northern Luzon, Philippines securely date the migration of hominins into the Philippines to ca. 70 kya (thousands of years ago). The direct route to reach Luzon from the Asian mainland is via Borneo, Palawan, through Mindoro and into Luzon. Our research focuses on Mindoro Island as a potential stepping stone to the main Philippine Archipelago. While Palawan and Luzon have produced evidence for early human occupation, no systematic research on the prehistory of Mindoro has been conducted until now. We report on recent archaeological investigations at the Bubog rockshelter sites on the small island of Ilin just off the coast of Mindoro. The excavations produced evidence of stratified sequences of human habitation at the two rockshelter sites in the form of dense shell middens that date to ca. 11 kya onwards. They provide direct evidence on how variability in landscape formation, sea levels, and landmass during the terminal Pleistocene and early Holocene influenced the behavior of early human populations. Numerous species of molluscs were recorded and provisional results indicate variations in the invertebrate faunas throughout the stratigraphic sequences, resulting from sea level rise and the establishment of coral reefs between Ilin and Mindoro at the end of the Pleistocene. Our results contribute substantially to our understanding of the processes of human island adaptation, complement ongoing research into Island Southeast Asia's paleogeography, and enhance current knowledge of prehistoric subsistence strategies across the region.

Keywords: Pleistocene–Holocene adaptations, Philippine archipelago, foraging strategies, island adaptations, Sundaland and Wallacea, hominin migrations

Dedication:

This article is dedicated to Dr. Sabino Padilla, Jr., one of the authors, who recently passed away. Abe, as he is commonly known, was one of the pioneers in Mindoro Island research having worked with different Mindoro Mangyan groups since the 1980s. As we ventured in looking for archaeological sites in 2010, Abe, already diagnosed with stage IV colon cancer, mustered his strength and facilitated the research with the community. He also participated in the surveys. His passion for utilizing GIS and mapping to help the Indigenous People's cause has earned him a place in the hearts and memories of the people he loved and served.

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Introduction

The Philippines consist of 7107 islands located at the northern limits of Wallacea and northeastern fringes of the islands of Southeast Asia. They are separated from Borneo to the southwest by the Sulu Sea, from mainland Southeast Asia to the west by the West Philippine Sea, Taiwan to the north by the Luzon Strait, Sulawesi to the south by the Celebes Sea, and to the east by the Philippine Sea.

The Philippine archipelago straddles two distinct biogeographic zones, Sundaland and Wallacea, with Palawan located on the northeastern fringes of the Sunda Shelf; hence it has fauna and flora whose closest relatives are within Island Southeast Asia (Madulid 1998). A posited land bridge either in the Upper Pleistocene (Fox 1970; Earl of Cranbrook 2000) or more likely in the Middle Pleistocene (Heaney 1985; Pawlik and Ronquillo 2003; Piper *et al.* 2008, 2011) perhaps facilitated the colonization

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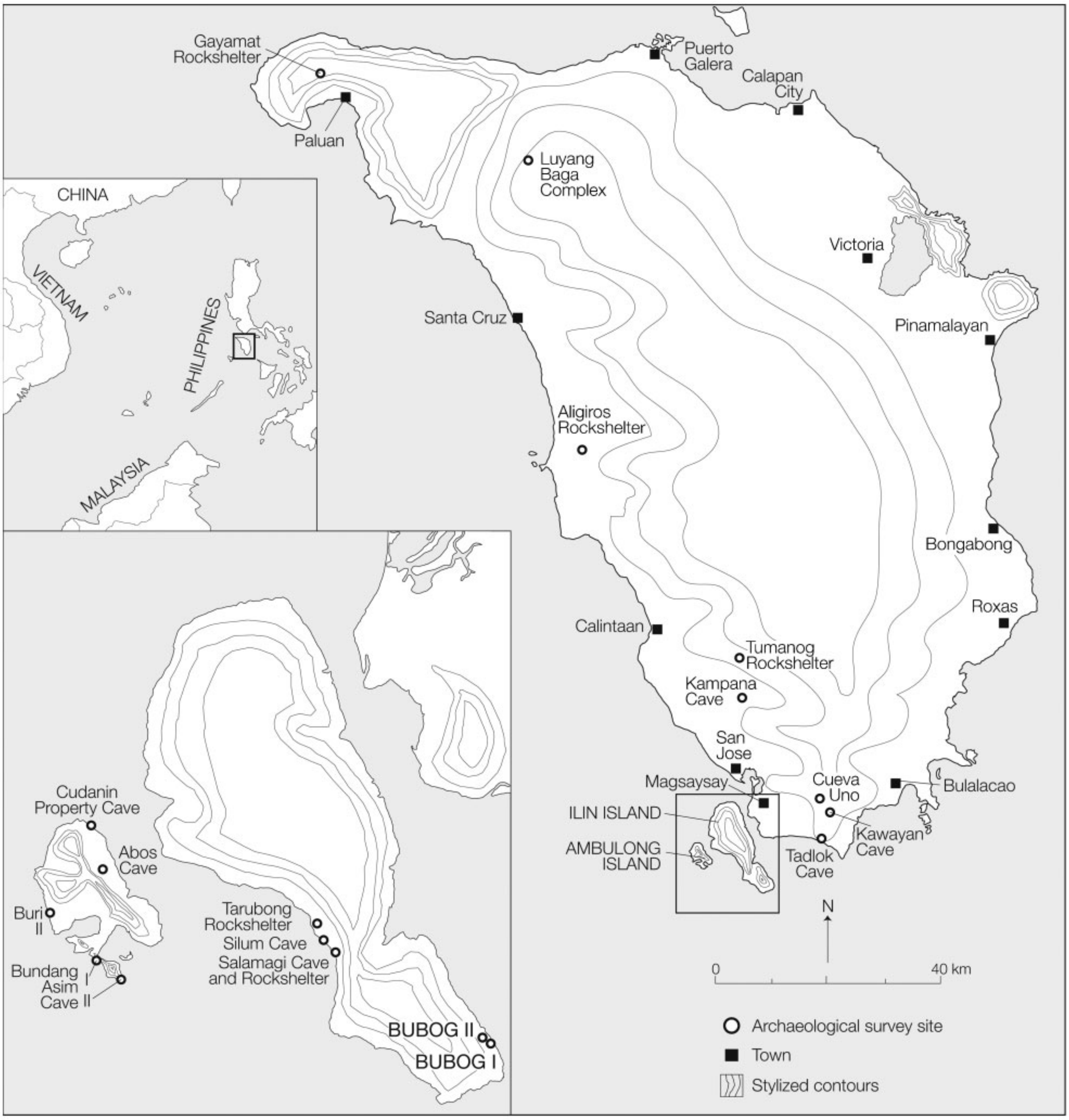

Figure 1 The Philippine archipelago showing the position of Mindoro and Ilin, and the locations of Bubog I and II (inset).

of Palawan by the inhabitants of Sundaland, potentially including early hominins. The main archipelago islands of Luzon, the Visayas and Mindanao, situated in Wallacea on the other hand, have never been physically linked to any mainland, and a sea crossing has always been needed to reach them (Heaney 1993; Oliver and Heaney 1996; Esselstyn *et al.* 2010). As a result these islands contain remarkable endemic vertebrate fauna found nowhere else in the world (Heaney 1986).

As early as the 1960s excavations on Palawan Island produced evidence that anatomically modern humans had arrived in the Philippines ca. 35 kya ago (Fox 1970, 1978; Détroit *et al.* 2004; Dizon *et al.* 2002). They had presumably crossed from Borneo where a human presence at the Niah Caves dates to more than 50 kya (Harrisson 1957, 1958; Barker *et al.*, 2007). More recently excavations in Callao Cave, northern Luzon has produced the remains of a third metatarsal provisionally assigned to *Homo sapiens* and dated to 66.7 ± 1 kya using U-series ablation (Mijares *et al.* 2010; Klein 2008; Mellars 2006).

To reach Luzon from the Asian mainland two routes are likely: one via the Sunda Shelf and Borneo to Palawan, then Mindoro and on into Luzon; the other through the islands of the Sulu Sea and Mindanao then northwards through the Visayas. Another possible route would be from the mainland, possibly through Taiwan and the northern Philippine Batanes Islands and into Luzon. There is, however, no evidence of any human presence in the Batanes Islands prior to ca. 4 kya, and the ocean currents between Taiwan, the Batanes Islands, and the Babuyan Islands to their south are notoriously unpredictable and violent (Bellwood and Dizon 2005).

Mindoro is a strategically located land formation between Borneo/Palawan and the other Philippine islands that may have acted as a stepping stone in the colonization of the Philippine archipelago. Thus, it is well positioned for testing different hypotheses regarding patterns of human movement and colonization. The island was never connected to the Southeast Asian mainland (via the emerged Sunda Shelf) during the Pleistocene, and like other islands in the Philippine archipelago it has endemic island fauna found nowhere else in the world, including the diminutive buffalo *Bubalus mindorensis* and endemic pig *Sus oliveri* as well as numerous murid rodents. While the islands of Palawan and Luzon have produced evidence for early modern human occupation (Fox 1970; Mijares *et al.*, 2010; Pawlik and Ronquillo 2003; Paz 2005), and information on the faunal communities that once inhabited them (de Vos and Bautista 2001; Heaney *et al.* 2011; Ochoa and Piper in press; Piper *et al.* 2009, 2011), Mindoro remains an archaeological and biogeographic terra incognita with respect to early human colonization, adaptation, and the evolutionary history of the faunal communities it supported in the past. With these archaeological and paleobiogeographical lacunae in mind the present archaeological research project was initiated.

Our multidisciplinary project was designed to identify traces of early human colonization of the Philippine archipelago, and to explore how changes in landforms and sea levels might have influenced the mobility of human populations, and how they utilized and adapted to the different environments they encountered on Mindoro. The coastlines of Mindoro have remained relatively stable throughout the Pleistocene (with reference to bathymetric maps) and archaeological sites in this region have the potential to produce evidence of a diverse range of human subsistence strategies and other behaviors, perhaps similar to those recently recorded in East Timor and on Talaud Island (O'Connor *et al.* 2011; Ono *et al.* 2010).

Initial surveys of karstic limestone formations in the southern part of Mindoro and the adjacent small islands of Ambulong and Ilin in 2010 identified more than 19 cave and rockshelter sites with evidence of past human occupation, in the form of ceramics, stone artifacts, shell middens, and animal bones (Porr *et al.*, 2012). Following the preliminary survey, a small number of sites were investigated in more detail to determine the spatial and temporal extent of their archaeological deposits, and hence the potential they held for further archaeological research. Two rockshelter sites, Bubog I and Bubog II, located on Ilin, an island 5 km south of the city of San Jose off the southwestern coast of Mindoro in the West Philippine Sea had the best archaeological records.

The island of Ilin, oriented southeast-northwest, is ca. 17 km in length, with a maximum breadth of 7 km, and consists primarily of karstic limestone formations with some volcanic geology in its northeastern corner. At present Ilin and Mindoro are separated by a channel ca. 900–1300 m wide (FIG. 1). The rockshelter sites of Bubog I and II are located on the southeastern side of the island ca. 7.5 km from the southwest coastline of Mindoro at ca. 30 masl and ca. 40 masl, respectively. Preliminary investigations of Bubog I and II at the end of 2011 indicated that both contained rich, well-stratified archaeological deposits consisting primarily of large shell middens and a stone artifact "technology" primarily designed by the human foragers for breaking open large marine shells to extract the soft bodies within them (Porr *et al.* 2012). Two ^{14}C dates, one at the base of the shell midden, and another towards the top of the Bubog I sequence suggests that the deposits accumulated from the terminal Pleistocene into the Holocene. Post-excavation analyses show marked variability among the faunal compositions of both stratigraphic sequences, suggesting that the human foragers on Ilin were responding to changes in local aquatic environments as a result of the marine transgression and climatic amelioration at the end of the Pleistocene and into the Holocene.

Excavations at Bubog I and II

The excavations at Bubog I and II were undertaken with permission from the National Museum of the Philippines as the national authority responsible for the protection of archaeological and cultural heritage in the Philippines. The sites were excavated by stratigraphic unit using trowels and buckets, and recorded using a context recording system (Roskams 2001). Each stratigraphic unit and associated artifacts and ecofacts from that deposit were given a unique identifying number (layer number), and it is these numbers that are referred to in the text and illustrations (below). The majority of the sediments were sieved through large wooden sieve racks built on site, with a mesh size of 2 mm and all artifacts and ecofacts were removed, bagged, and recorded. A bag of at least 15 L of sediment from each stratigraphic horizon was transported to the beach where it was wet sieved through a 1 mm and 2 mm sieve rack in the sea. Another 5 L bag of sediment from each context was returned to the hotel 25 km away where it could be floated in fresh water. Water was poured into each sample and then agitated by hand to break up lumps of sediment. The material that floated (light

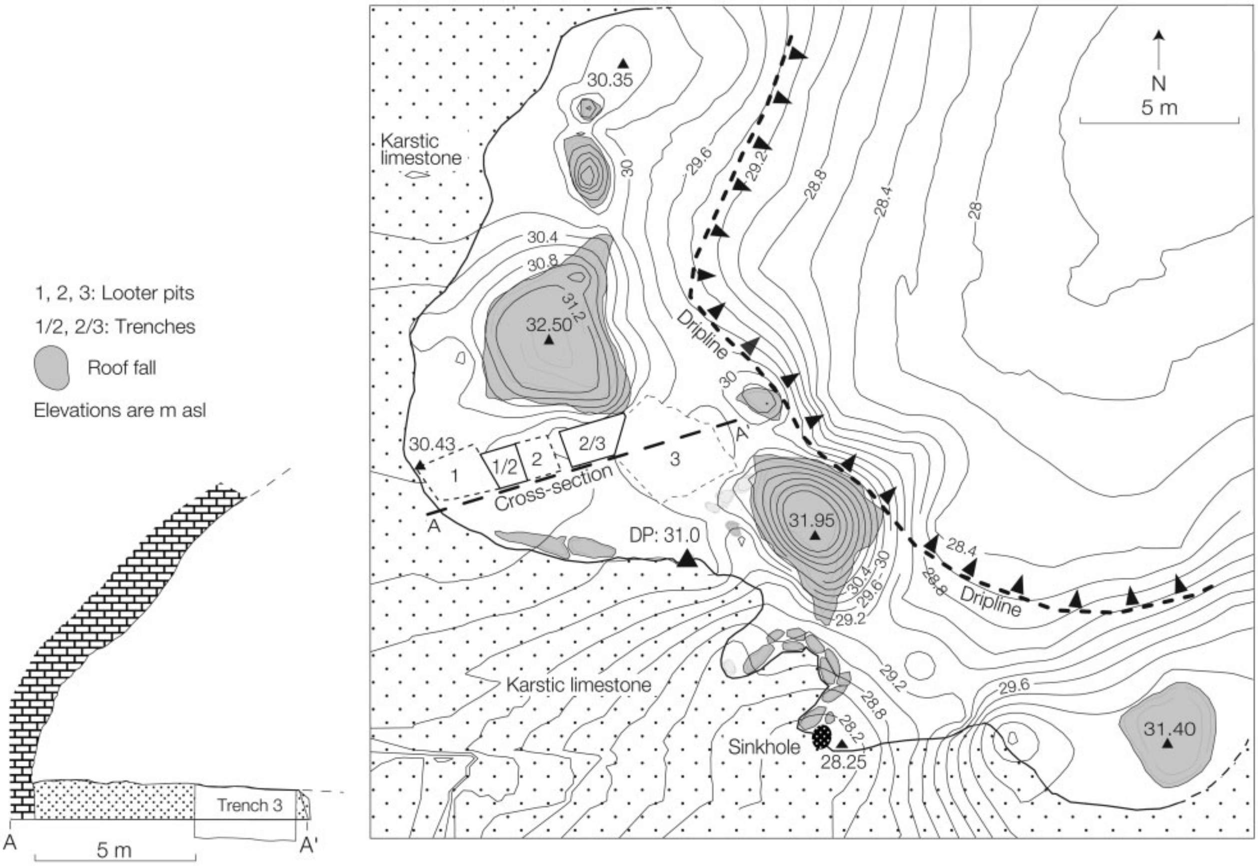

Figure 2 Plan of the treasure hunter pits and trenches dug to connect them through controlled excavation at Bubog I. A profile of the east wall above the excavation trenches is pictured on the left.

fraction) was poured into a 0.5 mm sieve and the organic remains collected. This whole process of washing the sediment was repeated three times. The collected light fraction materials were transferred to a thin cloth, labeled and hung to dry. For the materials that did not float (heavy fraction), these were wet sieved, then dried before sorting (Carlos 2012; Barker *et al.* 2011). The recovery strategy remained consistent throughout the excavated stratigraphic sequences of both sites to ensure temporal and spatial comparability within and between excavated contexts. This strategy resulted in the recovery of considerable quantities of large and small molluscs, pottery (upper layers only), terrestrial and aquatic vertebrate remains, stone artifacts, and macrobotanical remains.

Bubog I

Bubog I (National Museum Accession No. IV-2011-G3) is located on the eastern side of Ilin Island within Barangay Pawikan at 12°10′16″N, 121°07′52″E. The site faces northeast, is between 40–50 m long with a rock overhang in excess of 4 m wide (FIG. 2) and is situated at an elevation of 31 masl. The site was first identified in July 2011 during initial surveys of the southeastern side of Ilin Island (Porr *et al.* 2012). The owner of the site and his relatives had dug three pits through well-stratified archaeological sequences to a depth of ca. 1 m in the hopes that they would find gold or treasure. With only three days of the field season remaining the major effort was in the emptying and cleaning of the treasure hunter pits (Pits 1–3 with Pit 1 closest to the rockshelter wall) and the sampling of the shell midden. Associated with the shells were several pebbles and pebble fragments and some fish and mammal bones. The edges of the pits were straightened to provide vertical profiles for drawing, recording, and photographing. The rockshelter platform and walls were surveyed and a provisional recording and mapping of the site was undertaken. Auger drilling at the base of Pits 1 and 2 indicated at least another 1.5 m of deposits containing fragments of shell.

The team returned in November 2011 and the previously dug pits were joined using controlled excavation to produce a single east-west aligned profile from the rockshelter wall (west) almost to the lip of the platform (east) (FIG. 3). The integrity of the stratigraphic sequence was fairly consistent throughout the east-west-orientated trench, though shell fragmentation indicated greater reworking within stratigraphic horizons through human foot traffic and activities away from the wall of the rockshelter.

The upper two layers (Layers 1 and 2) consisted of dark brown loose and friable silty sands that represented redeposited sediments and an underlying, reworked

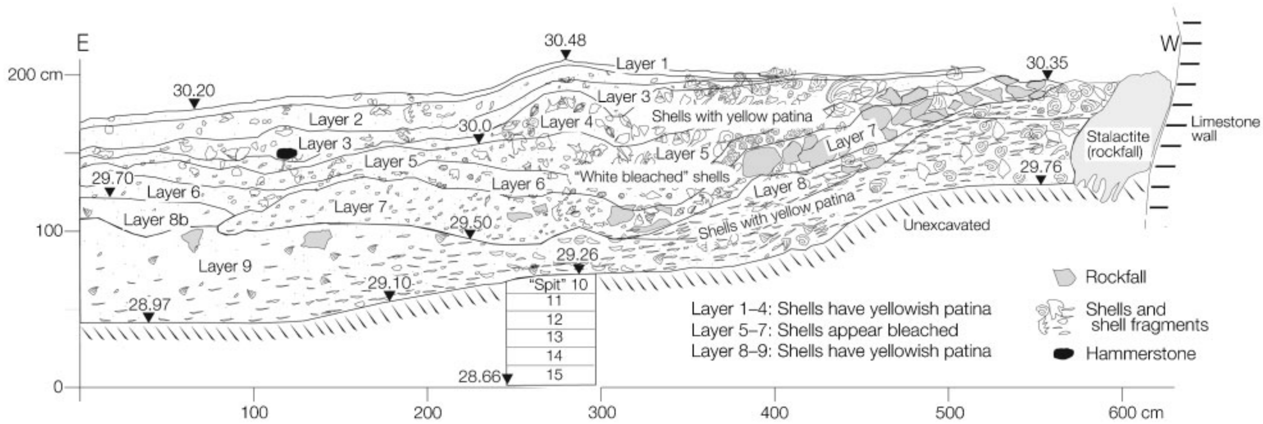

Figure 3 The south (north-facing) wall of the profile through the treasure hunter pits and excavation trenches from the limestone wall (right) in the west almost to the edge of the rockshelter platform in the east at Bubog I.

former surface deposit (upper deposit prior to illicit digging) (online supplement 1 http://www.maneyonline.com/doi/suppl/10.1179/0093469014Z.00000000090). These recent deposits overlay a sequence of four consecutive layers of shell midden. Layer 3 was a loose dark brown silty loam containing a densely packed shell midden with a high proportion of large gastropods *Lambis*, *Trochus*, and *Turbo,* and the bivalve *Tridacna* (online supplement 2 http://www.maneyonline.com/doi/suppl/10.1179/0093469014Z.00000000090) in association with some stone artifacts, terrestrial and aquatic vertebrate remains, and a few ceramic sherds. This layer, like the underlying deposits, sloped from the rockshelter wall towards the west at varying, but increasingly accentuated degrees. Below Layer 3 was a dark brown friable silty loam (Layer 4) containing another densely packed shell midden, again consisting of high concentrations of edible large marine gastropods such as *Lambis*, *Trochus, Turbo,* and the bivalves *Tridacna* and *Hippopus,* hammerstones and animal bones, but no pottery. Under Layer 4 was Layer 5, a friable dark brown silty loam deposit (likely a shell midden) with stone artifacts, and faunal remains. The composition of the molluscan fauna in this layer was very similar to that in the stratigraphic layers above with the gastropods *Conus*, *Lambis*, *Lunella*, and *Strombus*, and the large bivalve *Tridacna* represented. Layer 6 was loose dark brown sandy clay loam with high concentrations of molluscs. Many of the species present in Layers 5 and above such as *Strombus sinuatus*, *Lambis lambis*, and *Turbo petholatus* were still well represented, but there was a complete absence of *Tridacna*.

Layer 7 consisted of loose dark brown silty soil containing very large fragments of angular limestone, especially at the west end of the trench close to the wall of the rockshelter. Most fragments were angled downwards from west to east suggesting that they had dropped from the rockshelter wall onto the sloping ground. There was a marked decrease in the numbers of shells recovered from this deposit, and the molluscan remains appeared to be more fragmented than those recovered from the over- and underlying deposits. It is possible that a relatively substantial rockfall had occurred during this phase of sediment deposition limiting occupation at Bubog I. Some molluscan species associated with coral reefs were still present but the assemblage was now dominated by the community's exploitation of rocky shorelines, sandy bottoms, and brackish water.

Beneath the rock fall was Layer 8, a friable dark reddish brown sandy silty loam containing large concentrations of the mangrove bivalve *Geloina coaxans* in association with high frequencies of the estuarine/mangrove species *Terebralia sulcata*. The considerable difference between the composition of the molluscan fauna in this deposit and those above could easily be discerned within the excavated profiles of Bubog I (FIG. 4). The *Geloina* layer was underlain by Layer 9, a loose dark reddish brown sand clay loam loaded with densely packed, complete, and fragmented *Geloina coaxans* and broken *Terebralia*

Figure 4 The east end of the south wall of the Bubog I east-west trenches showing the differences in the molluscan taxa in the archaeological strata.

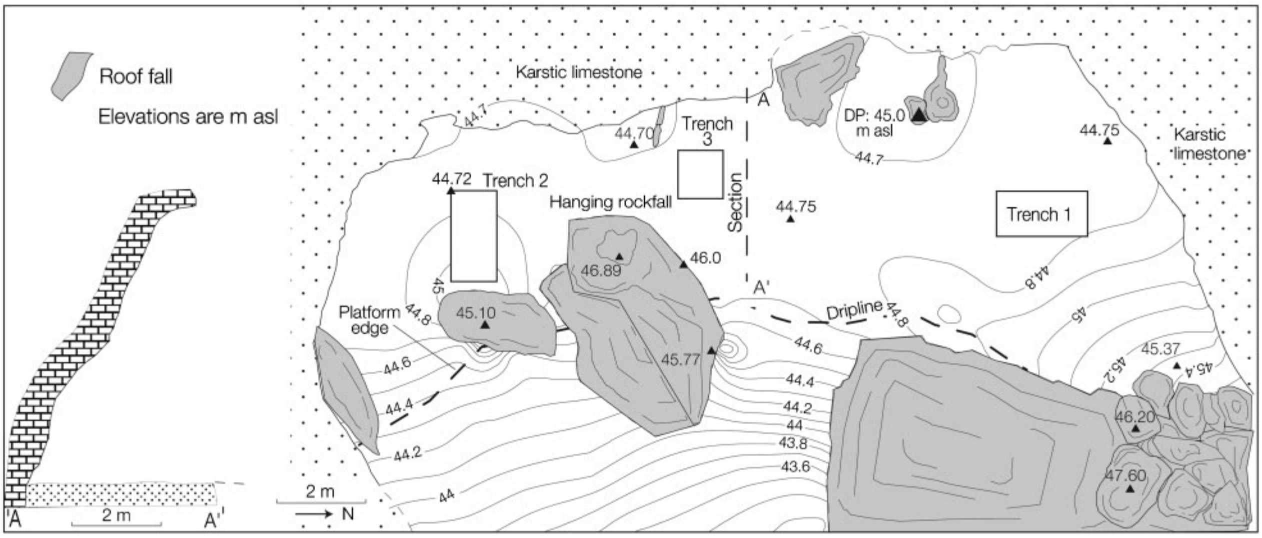

Figure 5 Plan of the excavation trenches at Bubog II.

shells in association with hammerstones. These lower layers also produced high frequencies of extremely large propodi and fixed and movable pincers of several species of large mud crabs *Scylla serrata,* coconut crabs *Birgus latro,* and possibly *Charybdis*, and chitons (*Polyplacophora*) of different species. Though the shells of the large terrestrial snails *Cyclophorus reevei* and *Hemiglypta semperi* were found throughout the archaeological sequence, they appeared in high concentrations in Layers 8 and 9. The *Hemiglypta semperi* in particular demonstrated a specific breakage pattern through the body whorl that indicated they had been integrated into the human diet at Bubog I. Layer 9 represented the basal deposits of the shell midden, and there was a marked transition between this and the underlying Layer 10. Layer 10 consisted of fine homogenous reddish brown silty clay with considerably fewer shells in its matrix. At the end of the 2011 field season a 1×1 m test trench was dug through Layer 10 in 0.1 m intervals to a depth of 0.6 m. Numerous bones of relatively large marine fish were recovered along with some estuarine, mudflat and rocky shoreline molluscs, indicating a continuing human presence at Bubog I to the base of the excavated deposits. These observations suggest that there are still earlier sequences of habitation at Bubog I yet to be revealed.

Two ^{14}C samples were sent to the Waikato Radiocarbon Laboratory in New Zealand for dating and to provide a preliminary temporal span for the accumulation of the shell middens. A *Conus* shell from Layer 5 in Trench 1 returned a date of 5774–5583 CAL B.P. (1 sigma) or 5891–5525 CAL B.P. (2 sigmas; WK32984). There was no evidence of recrystallization, the shell was made of aragonite and the $\delta^{13}C$ value was 0.2 ± 0.2. There is no marine shell reservoir correction factor for Palawan/Mindoro, but nearby values suggest 0 would not be far from wrong in most cases (Fiona Petchey, personal communication 2011). A fragment of *Canarium hirsutum* from Layer 9 produced a date of 11,083–10,787 CAL B.P. (1 sigma) and 11,100–10,760 CAL B.P. (2 sigmas; WK 32983; $\delta^{13}C$ value of -24.2 ± 0.2). Dating a nut fragment avoids problems associated with the potential in-built ages associated with wood and can be considered a reliable date (Schiffer 1986).

Bubog II

Bubog II (National Museum Accession No. IV-2011-M3) is located at 12°10′25″N, 121°07′42″E and is about 400 m inland from Bubog I and is at an elevation of 45 masl. The rockshelter faces east and covers a leveled rectangular platform ca. 6 m in width. A survey in early July 2011 indicated that the rockshelter platform was surrounded by high ceilings and walls to the north, south, and west, and two large rock falls to the east. No illicit digging or other disturbances were observed, but a few scattered fragments of black-slipped pottery and several shells, including the bivalves *Tridacna* and *Geloina coaxans* and the gastropod *Trochus* were observed on the ground surface. Augering of the platform was mostly unsuccessful due to the very loose sediment, but one core through wet sediment under a dripping stalactite indicated that sediments consisted of clay silt loam, with inclusions of a few small gastropod fragments, to a depth of 100 cm.

On returning to the site in November 2011 it was decided to determine the extent, both spatially and temporally, of the archaeological deposits that might exist within the rockshelter. Three trenches were excavated, with Trench 1 orientated north-south at the northern end of Bubog II, Trench 2 orientated east-west and of the same size at the south end, and Trench 3 was a 1×1 m sondage close to the modern

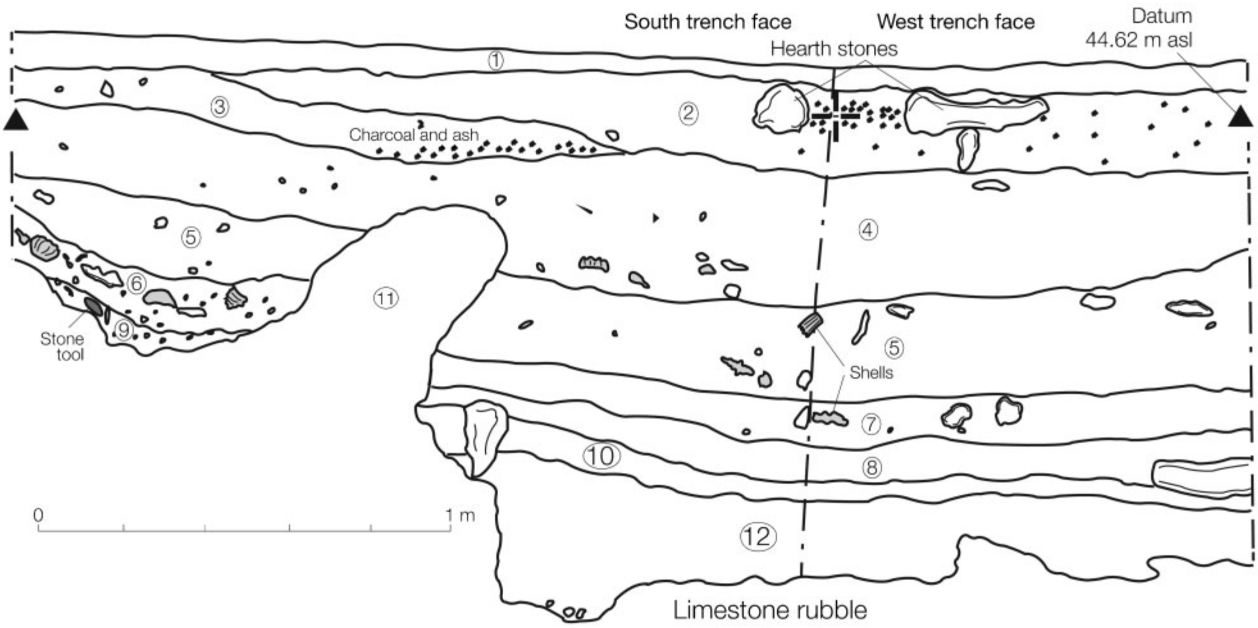

Figure 6 South (north-facing) and west (east-facing) profiles (trench faces) of Trench 2 at the south end of Bubog II showing the strata excavated. Illustration by P. Piper.

access to the rockshelter (FIG. 5). All trenches produced evidence of human activity, but the most comprehensive investigations during this initial study were undertaken in Trench 2.

After cleaning and the careful removal of loose wood and debris covering the surface of Trench 2, the contemporary modern ground surface deposit of loose mid-reddish brown sandy silt loam (Layer 1) was removed (FIG. 6). Beneath Layer 1 were two distinctive deposits (Layers 2 and 3) of reddish brown sandy silt loam at the eastern and western ends of the trench containing broken shells of molluscs including *Lambis*, *Tridacna*, and *Strombus*, and pottery (online supplements 3, 4 http://www.maneyonline.com/doi/suppl/10.1179/0093469014Z.00000000090). Located within Layer 2, in the southwestern corner of the trench (and extending beyond its limits) were three large limestone fragments with evidence of extensive burning surrounding a deposit containing a considerable amount of charcoal and ash. Two other similar structures were recorded in Trenches 1 and 3 within the subsurface (Layer 2). All these probable hearth features were covered by several centimeters of sediment indicating that they were not related to recent activity within the rockshelter and could be at least several centuries old.

Layer 4 was a dark reddish brown friable sandy silt loam that extended right across the trench, but was absent from the far northeastern corner. The layer contained relatively large amounts of shell including complete *Lambis lambis* shells. Underlying Layer 4 and extending across most of the trench was Layer 5, a friable yellowish red sandy silt loam containing relatively large quantities of complete and broken bivalves and gastropods from a range of different marine ecological niches. At the eastern end of the trench, Layer 5 was replaced by Layer 6, composed of friable yellowish red sandy silt loam containing a dense shell midden of intact or partially intact *Trochus*, *Lambis*, *Tridacna*, and other marine shells similar in proportions to those in the upper horizons at Bubog I. This deposit sloped steeply from fringing rock fall (Context 11) visible above ground level in the west, towards the east. It appeared to intermingle with Layer 5 suggesting the two deposits were contemporaneous. The most parsimonious explanation is that, as in Trench 1, the original shell midden (Layer 6) had survived intact in locations away from areas that had seen the most extensive human traffic (Layer 5). Underlying Layer 5 was a friable yellowish red sandy silt loam (Layer 7) that sloped slightly from east to west. In contrast to Layer 5, this deposit appeared to contain considerably more small gastropods such as *Nerita* and fewer large marine shells such as *Lambis*, *Conus*, and *Tridacna*. Layer 8 was friable dark reddish brown sandy silt loam with molluscan contents similar to those in Layer 7, but associated with a higher frequency of larger angular fragments of limestone. The inclusion of large fragments of limestone, probably resulting from roof fall, is an indication that this layer may correspond to Layer 7 at Bubog I where substantial ceiling debris was recorded.

Isolated at the west end of the trench, sandwiched between and overlying dense rock fall was a relatively hard and compacted dark reddish brown sandy silt loam sediment (Layer 9). This deposit could easily be distinguished from the overlying Layer 6 by the almost complete absence of large shells such as

Trochus, *Lambis*, and *Tridacna*, which points to the absence of a reef flat, and with a predominance of smaller gastropods such as *Nerita*. In a fashion similar to the association of Layers 5 and 6, it is possible that Layer 9 was an intact portion of the more disturbed Layers 10 and/or 12 to the west.

Layer 10 only existed at the west end of Trench 2, with the east end entirely occupied by rock fall (Context 11). This relatively thin layer of friable yellowish red sandy silt loam sloping slightly from east to west could be distinguished from the overlying Layer 8 by its higher frequencies of *Polyplacophora* and *Haliotis ovalis*. The latter is a shallow subtidal cobble-dwelling species that people may have collected from a depth of 3–5 m. The basal layer, Layer 12, consisted of a friable yellowish red sandy silt loam that overlay a dense impenetrable rock fall (Layer 13) across the trench. This layer extended to a maximum depth of 1.35 m below modern ground level before the limestone rubble was encountered, indicating the basal depth of archaeological deposits at the southern end of Bubog II.

Human Foraging, Environmental Change, and Sea Level Rise

The most abundant faunal remains recovered from the Bubog sites are invertebrates. In total, 38 gastropod and eight bivalve genera were recorded at Bubog I and 42 gastropod and 12 bivalve genera were found at Bubog II (identified at the species level). It was clear from the preliminary analyses that the species of molluscs were not randomly distributed throughout the archaeological deposits; certain species occurred in higher frequencies in some strata, but not in others. In this preliminary analysis, the presence and absence of different taxa was recorded, and the species were subdivided into different community affiliations dependent on their ecological niche and habitat preferences (online supplement 5 http://dx.doi.org/10.1179/0093469014Z.00000000090.S5). The resultant data indicated that there was a distinct change in the ecological habitats in which human populations occupying Bubog I and II were foraging from the terminal Pleistocene and into the Holocene. The reshaping of foraging strategies and the collection of particular invertebrate faunas could be closely linked to changes in local terrestrial and aquatic environments associated with the climatic amelioration at the end of the Pleistocene and into the Holocene.

No data for relative sea level changes in and around Mindoro have yet been published, but there is now a comprehensive modeling of sea level change recorded for the Sunda Shelf that includes Palawan, just to the southwest of Mindoro (Clark and Mix 2002; Hanebuth and Stattegger 2005; Hanebuth *et al.* 2000, 2009; Sathiamurthy and Voris 2006; Voris 2000). Although not ideal, the reconstructions suggest a relationship between human foraging strategies at Bubog I (currently the best studied of the two Bubog assemblages) and related changes in sea levels around Mindoro from the end of the Pleistocene through the Holocene as follows.

At the end of the last glacial maximum (ca. 20–18 kya) global sea levels were on a rapid rise due to melting ice sheets, briefly interrupted by two plateaus at 14–13 kya and 12–11 kya that correlate with the Older and Younger Dryas stadials (Clark and Mix 2002; Fleming *et al.* 1998; Ganopolski *et al.* 2010; Hanebuth *et al.* 2000; Rohde 2005; Skakun and Carlson 2009). At around 15 kya, the sea level in the Sunda Shelf region was at 110 to 100 m below present mean sea level; at 13 kya it rose to about 80 to 70 m below present mean sea level and about 60 to 45 m below at the beginning of the Holocene. Between 9 and 8.5 kya, sea levels reached 20 m below present mean sea level and at around 7 kya, the Sunda Sea was more or less at present day levels.

The paleolandscape of Southern Mindoro and Ilin Islands was reconstructed by digitizing the 1998 bathymetry maps of NAMRIA (National Mapping and Resource Information Authority) (Mindoro 4305; Mindoro 4330) using ESRI ArcGIS 10. The points from specific depths were converted to contours to depict the rise of sea level. The present topography and coastline were generated using the 2011 Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2). Depressions were interpreted as possible paleolakes or submerged areas. The rise of sea levels around Ilin followed the Sunda Sea transgression record mentioned above.

The bathymetric data indicate that Ilin Island is currently separated from Mindoro by a narrow channel that reaches a general depth of −20 m to −24 m (FIG. 7A). But at ca. 11 kya when the lowest layers of the shell midden were being deposited in Bubog I and II the sea level was still approximately 60 to 45 m below present mean sea level, and Ilin Island would have been joined to Mindoro on its eastern side and been a part of a larger landmass that included several small islands south of Mindoro as well as the island of Ambulong on Ilin's western side. Our reconstructions suggest the presence of several lakes at today's San Jose Bay and between Ilin and Mindoro. The Caguray River would possibly have flowed into these lakes, and farther to the south it would have linked with the Irog River before entering the sea (FIG. 7B). This could have led to the development of an estuary, more or less located at the same latitude as the Bubog sites, with mudflats and mangrove swamps where human foragers would have collected large quantities of *Terebralia*,

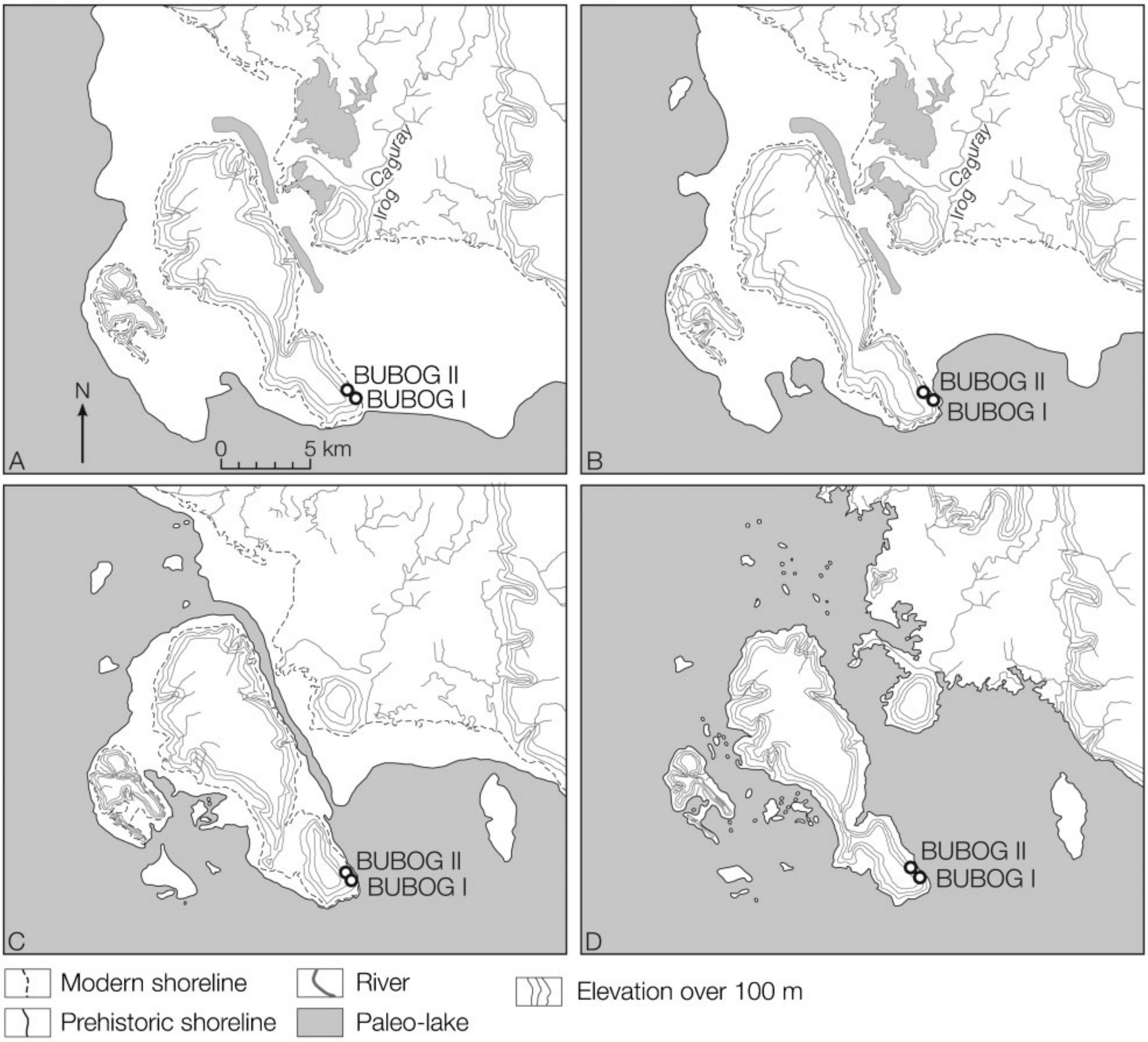

Figure 7 Sea level and landscape reconstructions of the Ilin Island and the southwestern Mindoro region. A) ca. 18 kya; B) ca. 10 kya; C) ca. 7.6 kya; D) ca. 6 kya.

Telescopium, *Geloina coaxans*, and *Neritina* along with a large number of mangrove and mud crabs.

Around most of the southern coast of Mindoro, and the coasts of Ilin and Ambulong there is a thin "band" of submerged land at ca. −20 m (or less) that, at present, provides habitat for corals and coral reef species, and then the land shelves rapidly to more than −100 m. It is likely that rocky shore species of shellfish would have always been available around these shores, but with lowered sea levels there appears to have been no locally available habitat for coral reef communities. The availability of rocky shore resources is also evident in the considerable number of chiton plates from numerous different species that were recovered from the early sequences of midden development.

By 9 to 8.5 kya the sea had risen to ca. 25 to 20 m below present mean sea level, high enough to start encroaching onto the shallow shelves and into the channel between Ilin and Mindoro. After ca. 8.5 kya the seas began to flood the channel and disconnect Ilin Island from Mindoro. The encroachment of the sea onto the landscape between Mindoro and Ilin is probably recorded by the appearance in Layers 7 and 8 at Bubog I of greater numbers of brackish water tolerant species such as *Nerita undata*, *Nerita exuvia*, and those adapted to shallow marine environments and sandy bottoms like *Angaria delphinus*, *Epitonium clathrus*, and *Vasum* sp.

After ca. 8 kya the channel between Mindoro and Ilin was already submerged to a depth of approximately 10 m (FIG. 7C) and the creation of lagoons and fringing coral reefs would have begun, and this is indicated in the Bubog stratigraphy by the increasing diversity of marine molluscs and the patchy distributions of those taxa adapted to mangrove, mudflats, and brackish water environments. At around 6 kya

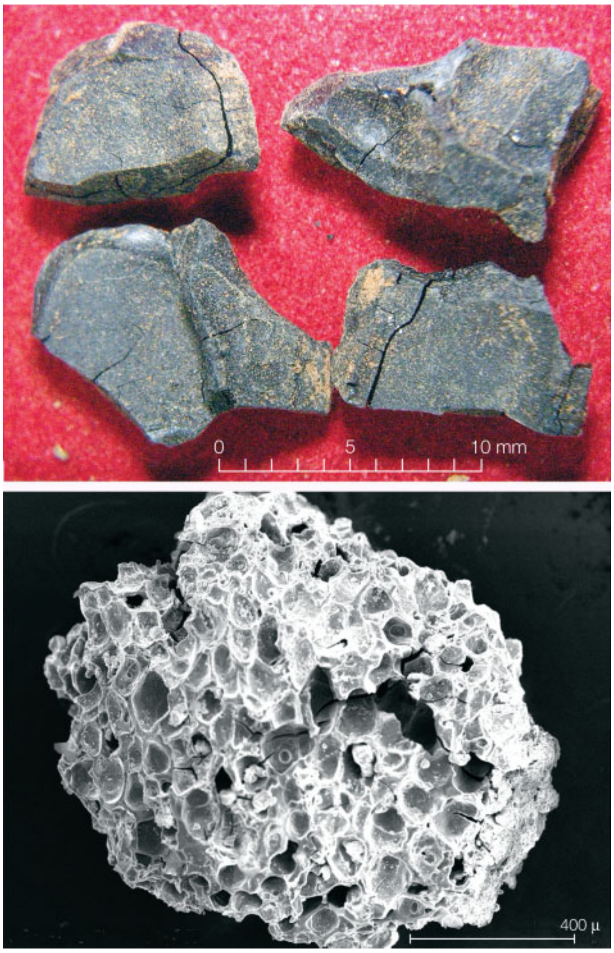

Figure 8 Photograph of *Canarium hirsutum* fragments (top) and SEM image of cf. *Dioscorea alata* (bottom).

more or less the same sea level and coastal landscape as today was created (FIG. 7D).

In Layer 5 at Bubog I and Layer 6 at Bubog II large bivalves of *Tridacna squamosa, Tridacna maxima*, and *Tridacna crocea* and *Hippopus hippopus* and *Hippopus porcellanus* in association with a diverse range of marine resources appear for the first time in the archaeological records of the two sites, indicating that full lagoon conditions had been achieved by perhaps 6.5 to 6 kya, and have continued thereafter with sea levels even rising to ca. 5 m above present level at 6 to 5 kya. Larger marshlands probably existed west and north of Ilin. Rocky shorelines and fringing mangroves continue to be a feature along the coastlines of Mindoro and Ilin today, but the invertebrate record at Bubog I and II suggests that these are much reduced in comparison to those that existed in the past.

The predominance of open lagoon molluscan communities continues into the upper layers of Bubog I and II where they are associated with fragments of pottery and, based on the likely timing for the introduction of ceramics to the region (cf., Bellwood 2005; Cameron and Mijares 2006; Fox 1970; Solheim 2002, 2008) date to within the last approximately 4000 years.

Macrobotanicals and Plant Use at Bubog I

The initial paleobotanical study concentrated on the remains recovered from Bubog I (Carlos 2012). Charred wood fragments were common within the "secure" archaeological sequence from Layers 3 to 9. Both hardwoods and softwoods are represented in the assemblages as well as a few seeds, charred fragments of parenchymous tissue, and nuts. The nut fragments were identified as *Canarium hirsutum,* an edible nut. Though the resin is concentrated in the bark of the tree, the nutshells also have some resin, and ethnographically, these hard and thick shells enclosing the kernel have been used as a fuel (Verheij and Coronel 1992; Bautista *et al.* 1994; Barker *et al.* 2011).

Several fragments of parenchymous tissue identified throughout the archaeological sequences at Bubog I were subjected to imaging by Scanning Electron Microscope (SEM) (FIG. 8). After comparison with the reference collection in terms of cell shape, size, and intercellular spaces, a sample was identified as resembling *Dioscorea alata* (see below).

The Vertebrate Remains of Bubog I and II

Although the vertebrates await full analysis, several families of common reef fish are represented in small numbers throughout the archaeological sequences from the terminal Pleistocene to mid-Holocene. These could have been caught around the coasts of the islands at any time.

Like many oceanic islands, Mindoro possesses a relatively impoverished terrestrial vertebrate fauna when compared to continental islands (e.g., Borneo, Sumatra, and Java to the west) and the mainland (Heaney 1985), but with high endemicity. This is emphasized by the paucity of large mammals known to have inhabited Mindoro, which includes the native *Rusa marianna, Bubalus mindorensis* (Tamaraw), and *Sus oliveri*. Of these, only pig, with a number of diagnostic molars assignable to the endemic Mindoro pig *Sus oliveri* (see Lucchini *et al.* 2005) has, as yet, been recorded in the Bubog vertebrate assemblages. This would seem to indicate that some terrestrial game supplemented the considerable numbers of molluscs and other invertebrates consumed at the sites (online supplement 6 http://dx.doi.org/10.1179/0093469014Z.00000000090.S6). The discovery of potentially diagnostic native and/or endemic murid rodent mandibles and maxillae (including loose teeth) present an excellent opportunity in the future to investigate the paleoecology and community structure of this poorly understood family on Mindoro (online supplement 5 http://dx.doi.org/10.1179/0093469014Z.00000000090.S5). The relatively high numbers of forms from the "larger" species of murid represented in the bone assemblages perhaps suggests that these were also

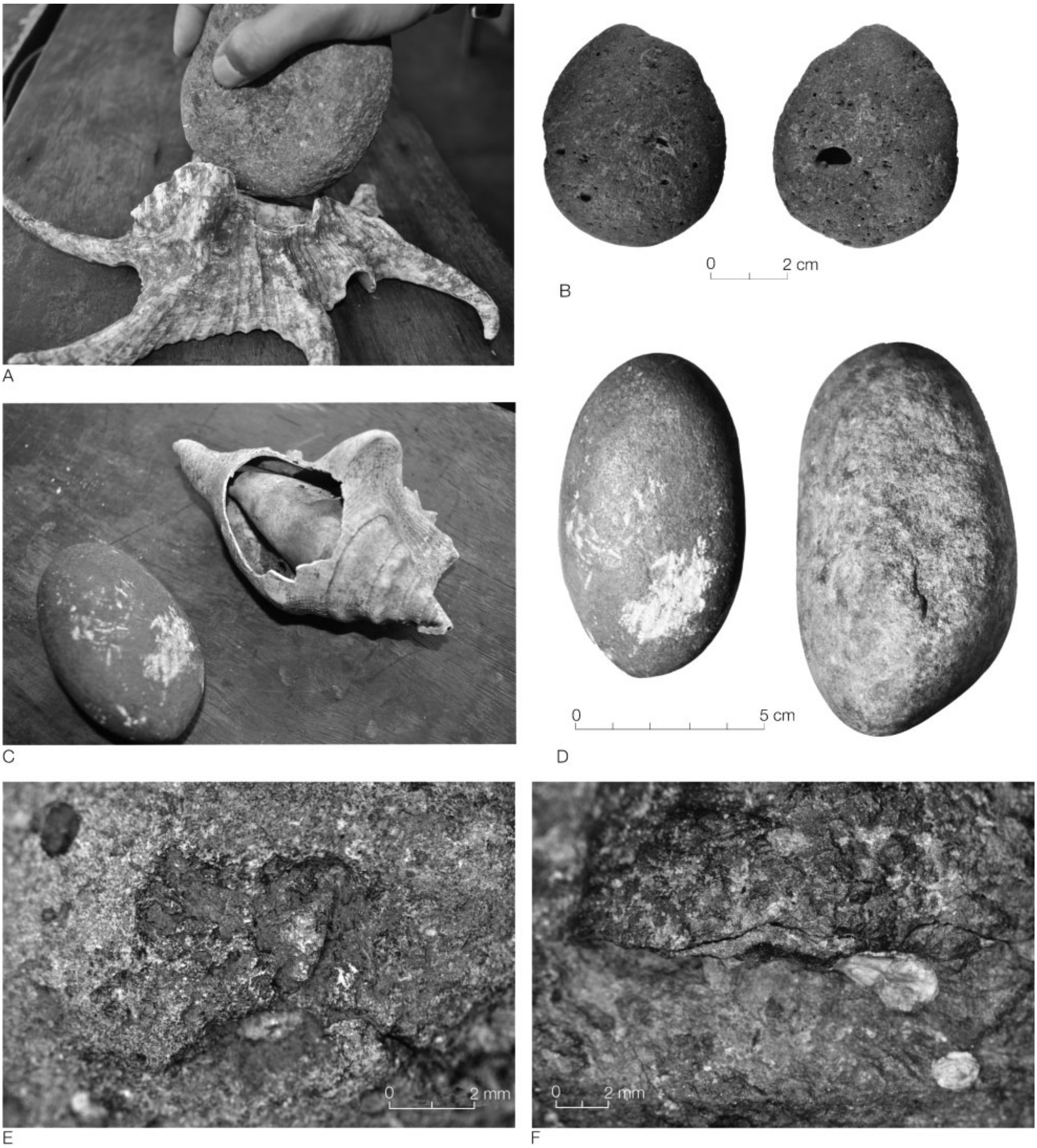

Figure 9 Lithic hammerstones from Bubog I. A) Demonstration of the use of a large basalt pebble as a hammerstone to break large gastropod shells; B) Scarred and battered surface of a pebble caused by its use as hammerstone; C) A contemporary hammerstone used to open a mollusc shell. Specimen donated to the Archaeological Studies Program by Mr. Rey Deyta. D) A modern hammerstone (left) showing modifications similar to the archaeological specimen (right); E) Microphotograph of battering marks on a pebble (no. IV-2011-G3-125) used as a hammerstone; F) Microphotograph of a break and cracks caused by hard impact on the battered area of a hammerstone (no. IV-2011-G3-027).

captured and eaten. A few bones of marine turtle, snakes and monitor lizards were also recorded throughout the archaeological sequences.

There is some indication that there is a change in foraging strategy in Layer 10 at Bubog I with less focus on fewer invertebrates and considerably more vertebrates represented, including large marine fishes.

Lithic artifacts and human behavior at Bubog

BUBOG I

An assemblage of 103 lithic artifacts was recovered at Bubog I during the two excavation campaigns in July and November 2011. The assemblage consists of 46 complete and/or fractured pebbles, 10 larger discoidal pebble fragments, and 47 flakes and shattered pieces from throughout the archaeological sequences. The

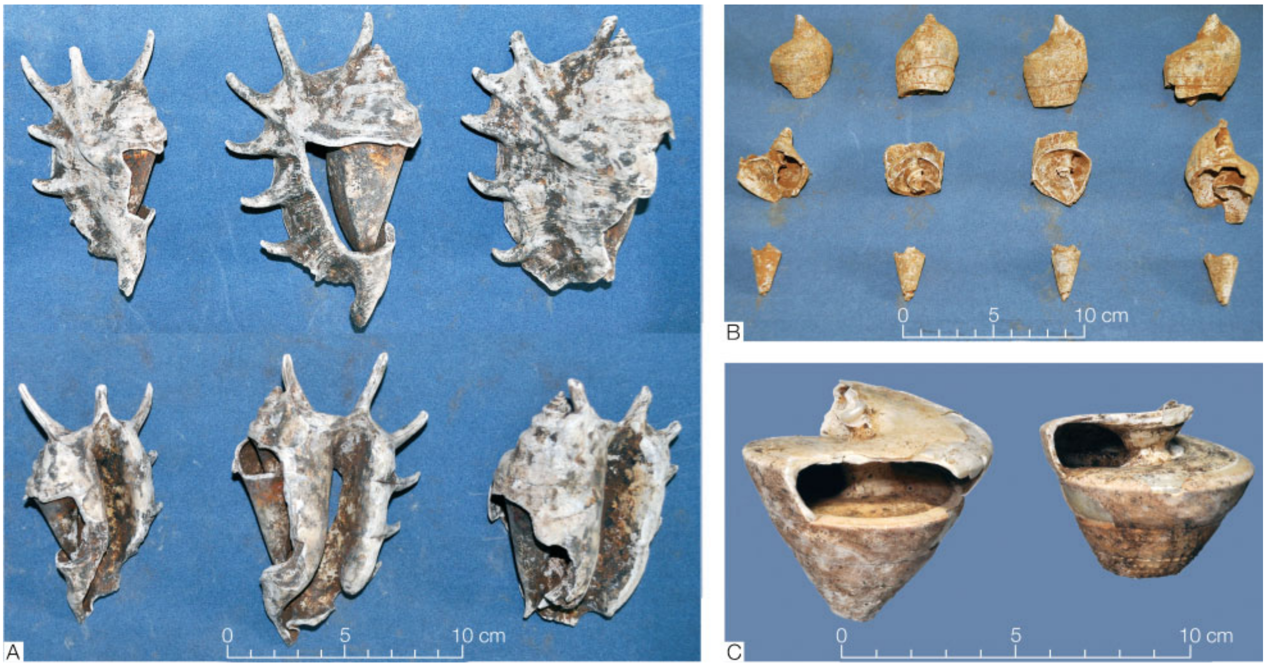

Figure 10 Different shell species and breakage patterns from the Bubog shell midden. A) *Lambis lambis* shells demonstrating the repetitive pattern of breakage by using hammerstones to extract the soft bodies; B) Smashed *Terebralia* shells showing a consistent pattern of breakage resulting from the use of hammerstones; C) *Trochus* shells showing a consistent pattern of breakage resulting from the use of hammerstones.

majority of artifacts were of igneous rocks like basalt, andesite, and amphibolite, but two chert pebbles and a rather exotic fragment of iron ore pebble, possibly limonite ($FeO(OH)\ x\ nH_2O$), together with one fragment of locally-acquired speleothem were also recorded. The largest complete pebble measures 117.7 mm in length, 92.0 mm in width, 58.6 mm in thickness, and weighs 970 g; the smallest pebble used as a hammer is 52.3 mm long, 32.0 mm wide, 21.2 mm thick, and weighs 55.2 g. Only three pebbles weigh more than 500 g, and the majority are significantly lighter. No obvious sorting by either size or weight was identified throughout the archaeological sequences. Visible surface damage such as pitting, battering, deep scars, and flaking resulting from hard impacts indicated that the pebbles had been used as hammerstones (FIG. 9 E, F). The function of the hammerstones and the choice of raw material for hardness and impact-strength were evident within the mollusc assemblages. In the upper layers specific repetitive breakage patterns through the body whorl of large gastropods such as *Lambis lambis* (FIG. 10) and *Conus* as well as larger dimples appearing preferentially on the flat surfaces of the pebbles demonstrate clearly that the hammerstones were utilized to break mollusc shells and remove the soft bodies from inside (FIG. 9 A, B). In the lower layers (Layers 9 and 10) nearly all the large *Terebralia* and *Telescopium* shells had been smashed through the body whorl as were the large marine gastropods recorded in succeeding layers.

The local inhabitants of the fishing village close to Bubog provided further evidence for the ancient use of the stone artifacts as shell-breaking hammerstones by donating one of the pebbles they still use for exactly the same purpose. The pebble showed damage patterns that were more or less identical to those found on the prehistoric artifacts (FIG. 9 C, D). The origin of the archaeological pebbles is uncertain, but they might have been collected locally along the beach in the past, few were found during a short survey in 2011. The local inhabitants of the village sometimes collect their hammerstones on the opposite side of the channel on Mindoro when they go to buy supplies.

In the Bubog I assemblage only five artifacts were made of siliceous materials (chert, quartz, and quartzite). Flake production for toolmaking is extremely rare and so far, only two possible chert cores, but no chert flakes, have been found during excavation, and one of these was an extremely shattered piece. Seven non-primary flakes made of basalt and andesite provided slim evidence for tool use, with five of these specimens demonstrating weak usewear traces along potential working edges. All other recorded flakes were simply fragments that had unintentionally broken off the pebbles as they were being used as hammerstones.

Six pebbles and one larger fragment show surface alteration caused by heat. In Layer 8, Trench 1/2, four small and weathered lumps of red ochre were found, possibly indicating the processing of colorants at the rockshelter.

BUBOG II

A small assemblage of 20 lithic artifacts was recovered at Bubog II during the two-week excavation in November 2011. It consists of seven complete but damaged pebbles, two pebble fragments, and 11 flakes and shattered pieces from throughout the archaeological sequences. All lithic artifacts are of igneous stones like basalt and andesite. No cores or flakes made of chert were found, and four smaller flakes made out of shell were recovered. The largest pebble, in fact only a medial fragment, measures 90.0 mm in length, 75.0 mm in width, 62.2 mm in thickness, and weighs 485 g; the next in size is an ovoid pebble of 93.4 mm in length, 75.2 in width, and 39.7 mm in thickness, and has a weight of 371 g. The smallest pebble used as a hammer is 57.4 mm long, 52.0 mm wide, 30.0 mm thick, and weighs 140.4 g. At least two pebbles were exposed to heat; also two larger burnt speleothem fragments were collected. The pebbles and fragments thereof show the same damage patterns such as pitting, battering, deep scars, and cracks as those found at Bubog I. The same function as shell-breaking hammers can be assumed. The only intentional flakes seem to have been produced from shell, indicating prehistoric activities other than the breaking of shells at Bubog II. They possess typical attributes of knapped flakes like platform remnants, bulbs of percussion, and dorsal negatives. Three of the flakes have sharp edges that could have been used for cutting activities on soft material. However, no wear traces along the edges are apparent. At neither site was there evidence for the ornamental use of shells.

Discussion and Conclusions

The initial surveys of Mindoro and Ilin indicated that the karstic limestone region in the southern part of Mindoro had archaeological sites. Though sometimes disturbed by illicit digging, these archaeological sites within caves and rockshelters contain well-stratified sequences. Both Bubog I and II possess stratified sequences presenting evidence of human habitation in the form of dense shell middens, with smaller numbers of aquatic and terrestrial vertebrate bones, paleobotanical remains, and stone artifacts. The two rockshelters have similar chronological sequences. The similarity in the archaeological records of the two sites adds confidence to our interpretations of human foraging strategies in relation to the dramatic changes (including sea level rise) that occurred in local and regional environments at the end of the Pleistocene and into the Holocene. The main focus of study so far has been on Bubog I where the stratification remains almost completely intact, whereas the distribution of molluscan taxa and evidence of sedimentary reworking in Trench 2 at Bubog II (with the exception of Layers 6 and 9) will require further analysis.

Though shell middens are relatively common in Island Southeast Asia (Szabó and Amesbury 2011) and are often used to describe human foraging behavior and environmental change (Ono *et al.* 2010; O'Connor *et al.* 2011; Bautista 2001; Lewis *et al.* 2008; Szabó 2009), the archaeological record at Bubog I and II on Ilin Island is unique in that a direct correlation can be observed between human foraging strategies and environmental change (Dunn and Dunn 1977; Erlandson and Fitzpatrick 2006).

The occupants of Bubog I and II at 11 kya inhabited rockshelters that overlooked a river valley and estuary with dense mangrove swamps and mudflats where they foraged for large mud crabs and bivalves of *Geloina coaxans*, and the gastropods *Terebralia* spp and *Telescopium* spp. Evidence that their foraging ranges extended farther around the coasts of Ilin (and perhaps Mindoro and Ambulong) is recorded in the presence of rocky shore species, particularly Littorinidae, Trochidae, and Turbinidae, and the considerable numbers of different species of chiton they must have levered off the rocks present in the archaeological deposits. They also collected substantial numbers of large terrestrial snails; the repetitive breakage patterns of the body whorl tell us they ate snails along with the aquatic molluscs they collected. During the later Holocene on the northern Philippine Batanes Islands, the consumption of terrestrial snails has also been proposed by Szabó and colleagues (2003). Terrestrial snails, *Camaneaids*, are still eaten by people today who boil them to remove the mucus. Further afield, huge middens of land snails have been recorded in Late Pleistocene and Holocene Hoabinhian sites in Vietnam (Rabett *et al.* 2011). In addition, the presence of *Melanoides maculata* throughout the assemblages would seem to suggest constant access to freshwater supplies even after the flooding of the Caguray River channel due to the rising sea level until fairly recently. Alternatively, the shells were imported from elsewhere on the island where freshwater is present.

A date of 11,100–10,760 CAL. B.P. (Wk-32983) on a fragment of burnt *Canarium hirsutum* shell and its presence throughout the stratification at Bubog I is evidence that the inhabitants of the sites were collecting and utilizing this fruit for oil and protein (Marcone *et al.* 2002) and possibly for fuel. In the Philippines, only four other samples of this species have been dated; all were derived from the Ille site in northern Palawan. The oldest of the samples from Ille (accession no. IV-1998-P-19761) yielded an uncalibrated date of 9220 ± 45 B.P. (OxA-21179) or 10,508–10,253 CAL. B.P. (95.4% probability). Samples yielding older dates were, however, collected from Seraba, Papua New Guinea, with an uncalibrated ^{14}C date of 14,000 B.P. (Yen 1990: 262; Maloney 1996). The species from Seraba, however, is *Canarium indicum* and not *Canarium hirsutum* as in the Philippines.

From the initial five parenchymous tissue samples, only one (from Layer 8 at Bubog I) could be identified as cf. *Dioscorea alata.* Though the determination of the sample is not definite owing to the limited features that have been documented, its similarity with domesticated yam species is significant. The recovery of more *Dioscoreaceae* dating to the early Holocene (or possibly the terminal Pleistocene) corroborates evidence of early domestication of *Dioscoreaceae* already observed at the Ille site, Papua New Guinea, and Borneo (Denham *et al.* 2004; Paz 2005; Barton 2005) and suggests that these tubers were possibly already being managed in the landscape around the Bubog sites by the end of the Pleistocene.

In the succeeding millennia, and as the sea level rose and the channel between Ilin and Mindoro was flooded, the local human inhabitants modified their strategies from foraging primarily in mangroves, rivers, and mudflats between the islands and along rocky shores around the rest of the islands, to collection within marine and brackish water environments. By the early/mid-Holocene the depth of the sea between the islands had reached more than 10 m and watercraft would certainly have been required to cross from Ilin to Mindoro (if they had not been needed before). Some species of mollusc such as the large *Conus* live in deeper waters and it is possible that people would have needed to dive to collect them (cf., Szabó *et al.* 2003). Marine invertebrates are recorded up to the modern ground level at Bubog I where they are associated with pottery.

The only lithic technology identified in the archaeological sequence was the utilization of igneous pebbles as hammerstones. Use alterations of the surfaces of the pebbles, and the conspicuous recurrent breakage patterns in large molluscan shells indicated the stones were used for smashing the shells to extract the soft bodies. Any "flaking" that occurred appears to have been the result of unintentional fracturing when one hard object (the hammerstone) struck another (the shell). The simple "grab and smash" behavior (contra "smash and grab," Coutts and Wesson 1980) observed in the archaeological record from Ilin points to important issues with regard to lithic technology and its relationship to complexities in human behavior (e.g., Ambrose 2010; Dennell 2009; Habgood and Franklin 2008). If the lithic artifacts were recovered from a context without explicit evidence for their use with marine molluscs, they would have been classified as "Mode 0" (Clarke 1969; Toth and Schick 2009), produced by people demonstrating low technological sophistication. In fact, using simple igneous rocks as hammerstones, probably in combination with the natural limestone as anvils, was perfect for participating in a foraging strategy considered by many archaeologists to reflect complex modern human behavior (McBrearty and Brooks 2000; D'Errico *et al.* 2008; Habgood and Franklin 2008; Haidle and Pawlik 2010). Assemblages containing large numbers of flaked stone tools are known from terminal Pleistocene and Early Holocene sites in the Philippines (Dizon and Pawlik 2010; Fox 1970; Mijares 2002, 2005, 2008; Kress 1979; Patole-Edoumba 2002; Patole-Edoumba *et al.* 2012; Pawlik and Ronquillo 2003; Pawlik 2009; Thiel 1990). At Bubog I, the absence of a flaked tool assemblage equivalent to those found at other sites, therefore, could indicate that working activities that required flaked stone tools were usually conducted elsewhere. This might also suggest the occupation of Bubog I (and probably Bubog II as well) as a temporary camp or as a seasonal shelter, where only locally available resources were consumed. This interpretation is similar to the rockshelter's present use by the fisher families living at Bubog cove below the site, who use its northern platform as a shelter during typhoons.

So far our research has demonstrated that human populations occupying Bubog, and probably similar caves and rockshelters (yet to be fully investigated by our team) on Ilin Island managed to adapt fairly readily to changes in climate and environment that occurred at the end of the Pleistocene. Many of the diverse foraging, and perhaps even plant management strategies utilized throughout most of the Holocene were already in place by the end of the Pleistocene. The local inhabitants simply modified preexisting behaviors to compensate for changes in circumstance, and they appear to have maintained many technologies and techniques for extracting resources from the local environment up until fairly recently when foraging was finally replaced by sedentism and cereal agriculture (Bellwood 2005).

At Bubog I the latest in situ archaeological deposits identified so far date to the mid-Holocene, but the surface deposits contain handmade black pottery characteristic of the later Neolithic of the region, suggesting the site was still in use during this period. Bubog II likely holds the best records of late occupation where at least three hearths were identified below the surface layers, associated with black pottery, perhaps indicating relatively recent habitation of the site. Mijares (2008) has argued that preexisting foraging populations coexisted in the same regions of northern Luzon with migrant farmers (as the Ayta and other indigenous groups of the Philippines still do), and maybe the Bubog sites will provide further evidence of this on Ilin.

The lowest levels (Layer 10 in Bubog I) date to before ca. 11 kya and have shellfish from mangrove, mudflat, and rocky shore environments and an almost complete absence of taxa associated with coral reef environments, reflecting the trend in the preceding Layers 8 and 9. In addition several fish bones of large *Serranidae* were also recovered along with five worked bones, including a fishing gorge. These are the earliest bone artifacts so far identified in the Philippines and pushing the introduction of osseus technologies and marine fishing in the islands back several thousand years. Previously the earliest evidence of bone technology in the Philippines appeared in the form of polished bone tools at Ille Cave in Palawan and its association with a radiocarbon date from charcoal of 6663–6482 CAL B.P. (OxA-16095).

Below the shell midden layers at Bubog I, evidence for the exploitation of terrestrial resources and a change in sedimentation were found in an initial 1×1 m test pit (Layer 10). The availability of a larger land area and the proximity of a wide river valley with a variety of resources would have provided an ideal environment for Pleistocene hunter-gatherers. Due to its sharply dropping southern and western shelves the southwestern part of a greater Pleistocene Mindoro would have more or less retained its landscape and topography for several thousands of years, widely unaffected by changing sea levels rising from ca. 120 m below present mean sea level during the Last Glacial Maximum until –60 m at around 12 kya.

Thus, it is clear that further excavations on Ilin Island, and in the wider karstic regions of southern Mindoro, have the potential to produce considerably more important information on the Pleistocene human occupation of Mindoro, the Philippine archipelago and Island Southeast Asia as a whole.

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References

Ambrose, S. H. 2010. "Coevolution of Composite-Tool Technology, Constructive Memory, and Language. Implications for the Evolution of Modern Human Behaviour," *Current Anthropology* 51 (Supplement 1): 135–147.

Barker, G., H. Barton, M. Bird, P. Daly, I. Datan, A. Dykes, L. Farr, D. D. Gilbertson, B. Harrisson, C. O. Hunt, T. Higham, L. Kealhofer, J. Krigbaum, H. Lewis, S. McLaren, V. Paz, P. Pike, P. Piper, B. Pyatt, R. Rabett, T. E. G. Reynolds, J. Rose, G. Rushworth, M. Stephens, C. Stringer, and G. Thompson. 2007. "The 'Human Revolution' in Tropical Southeast Asia: The Antiquity and Behaviour of Anatomically Modern Humans at Niah Cave (Sarawak, Borneo)," *Journal of Human Evolution* 52: 243–261.

Barker, G., C. Hunt, and J. Carlos. 2011. "Transitions to Farming in Island Southeast Asia: Archaeological, Biomolecular and Palaeoecological Perspectives," in G. Barker and M. Janowski, eds., *Why Cultivate? Anthropological and Archaeological Approaches to Foraging-Farming Transitions in Southeast Asia*. Cambridge: Cambridge University Press: 61–74.

Barton, H. 2005. "The Case for Rainforest Foragers: The Starch Record at Niah Cave, Sarawak," *Asian Perspectives* 44 : 90–106.

Bautista, A. 2001. "An Analysis of Animal Remains Recovered from Balobok Rockshelter, Sanga-Sanga, Tawi-Tawi, Province," unpublished Master's thesis, University of Santo Tomas, Philippines.

Bautista, O. K., R. R. C. Espino, J. B. Sangalang, H. L. Valmayor, and P. C. Tabora. 1994. "Status and Importance of Horticulture," in O. K. Bautista, ed., *Introduction to Tropical Horticulture*. Los Baños: SEAMEO SEARCA and UPLB.

Bellwood, P. 2005. *First Farmers: The Origins of Agricultural Societies*. Oxford: Blackwell Publishing.

Bellwood, P., and E. Dizon. 2005. "The Batanes Archaeological Project and the 'Out of Taiwan' Hypothesis for Austronesian Dispersal," *Journal of Austronesian Studies* 1: 1–31.

Cameron, J., and A. S. B. Mijares. 2006. "Report on an Analysis of Spindle Whorls from Callao Cave, Penablanca, North-east Luzon, Philippines," *Hukay, Journal for Archaeological Research in Asia and the Pacific* 9: 5–13.

Carlos, J. 2012. "Archaeobotany of Bubog, Ilin Island, Mindoro, Philippines," in H. Lewis, K. J. Chang, P. Lape, V. Paz, A. Peatfield, and O. Pryce, eds., *Abstracts of the European Association of Southeast Asian Archaeologists 14th International Conference September 2012*.s Dublin: University College Dublin, 11.

Clark, P. U., and A. C. Mix. 2002. "Ice Sheets and Sea Level of the Last Glacial Maximum," *Quaternary Science Reviews* 21: 1–7.

Clarke, G. 1969. *World Prehistory: A New Outline*. Cambridge: Cambridge University Press.

Coutts, P. J. F., and J. P. Wesson. 1980. "Models of Philippine Prehistory: A Review of the Flaked Stone Industries," *Philippine Quarterly Research in Culture and Society* 8: 203–259.

Denham, T., S. Haberle, and C. Lentfer. 2004. "New Evidence and Revised Interpretations of Early Agriculture in Highland New Guinea," *Antiquity* 78: 839–857.

Dennell, R. W. 2009. *The Palaeolithic Settlement of Asia*. Cambridge: Cambridge University Press.

D'Errico, F., M. Vanhaeren, and L. Wadley. 2008. "Possible Shell Beads From the Middle Stone Age Layers of Sibudu Cave, South Africa," *Journal of Archaeological Science* 35: 2675–2685.

Détroit, F., E. Z. Dizon, C. Falguères, S. Hameau, W. Ronquillo, and F. Sémah. 2004. "Upper Pleistocene *Homo Sapiens* from Tabon Cave (Palawan, the Philippines): Description and Dating of New Discoveries," *Comptes Rendus Palevol* 3: 705–712.

Dizon, E. Z., F. Détroit, F. Sémah, C. Falguères, S. Hameau, W. Ronquillo, and E. Cabanis. 2002. "Notes on the Morphology and Age of the Tabon Cave Fossil *Homo Sapiens,*" *Current Anthropology* 43: 660–666.

Dizon, E. Z., and A. F. Pawlik. 2010. "The Lower Palaeolithic Record in the Philippines," *Quaternary International* 223–224: 444–450.

Dunn F. L., and D. F. Dunn. 1977. "Maritime Adaptation and Exploitation of Marine Resources in Sundaic Southeast Asian Prehistory," in G. J. Bartstra, W. A. Casparie, and I. C. Glover, eds., *Modern Quaternary Research in Southeast Asia* 3, Rotterdam: A. A. Balkema, 1–28.

Earl of Cranbrook. 2000. "Northern Borneo Environments of the Past 40,000 Years: Archaeological Evidence," *Sarawak Museum Journal* 76: 61–110.

Erlandson, J. M., and S. M. Fitzpatrick. 2006. "Oceans, Islands, and Coasts: Current Perspectives on the Role of the Sea in Human Prehistory," *Journal of Island and Coastal Archaeology* 1: 5–32.

Esselstyn, J. A., C. H. Oliveros, R. G. Moyle, A. T. Peterson, J. A. McGuire, and R. M. Brown. 2010. "Integrating Phylogenetic and Taxonomic Evidence Illuminates Complex Biogeographic Patterns Along Huxley's Modification of Wallace's Line," *Journal of Biogeography* 37: 2054–2066.

Fleming, K., P. Johnston, D. Zwartz, Y. Yokoyama, K. Lambeck, and J. Chappell. 1998. "Refining the Eustatic Sea-Level Curve Since the Last Glacial Maximum Using Far- and Intermediate-Field Sites," *Earth and Planetary Science Letters* 163: 327–342.

Fox, R. B. 1970. *The Tabon Caves. Monograph of the National Museum of the Philippines*, No. 1. Manila: National Museum of the Philippines.

Fox, R. B. 1978. "The Philippine Palaeolithic," in F. Ikawa-Smith, ed., *Early Palaeolithic in South and East Asia*. Paris: Moutton: 59–85.

Ganopolski, A., R. Calov, and M. Claussen. 2010. "Simulation of the Last Glacial Cycle with a Coupled Climate Ice-Sheet Model of Intermediate Complexity," *Climate of the Past* 6: 229–244.

Habgood, P. J., and N. R. Franklin. 2008. "The Revolution That Didn't Arrive: A Review of Pleistocene Sahul," *Journal of Human Evolution* 55: 187–222.

Haidle, M., and A. Pawlik. 2010. "Pleistocene Modernity: An Exclusively Afro-European Issue?" *Bulletin of the Indo-Pacific Prehistory Association* 30: 3–8.

Hanebuth, T., and K. Stattegger. 2005. "Depositional Sequences on a Late Pleistocene-Holocene Tropical Siliciclastic Shelf (Sunda Shelf, Southeast Asia)," *Journal of Asian Earth Sciences* 23: 113–126.

Hanebuth, T., K. Stattegger, and A. Bojanowski. 2009. "Termination of the Last Glacial Maximum Sea-Level Lowstand: The Sunda-Shelf Data Revisited," *Global and Planetary Change* 66: 76–84.

Hanebuth, T., K. Stattegger, and P. M. Grootes. 2000. "Rapid Flooding of the Sunda Shelf: A Late-Glacial Sea-Level Record," *Science* 288: 1033–1035.

Harrisson, T. 1957. "The Great Cave of Niah: A Preliminary Report on Bornean Prehistory," *Man* 57: 161–166.

Harrisson, T. 1958. "The Caves of Niah: A History of Prehistory," *Sarawak Museum Journal* 8: 549–595.

Heaney, L. 1985. "Zoogeographic Evidence for Middle and Late Pleistocene Land Bridges to the Philippine Islands," *Modern Quaternary Research in SE Asia* 9: 127–143.

Heaney, L. 1986. "Biogeography of Mammals in SE Asia: Estimates of Rates of Colonization, Extinction and Speciation," *Biological Journal of the Linnean Society* 28: 127–165.

Heaney, L. 1993. "Biodiversity Patterns and the Conservation of Mammals of the Philippines," *Asia Life Sciences* 2: 261–274.

Heaney, L. R., P. J. Piper, and A. S. B. Mijares. 2011. "The First Fossil Record of Endemic Murid Rodents from the Philippines: A Late Pleistocene Cave Fauna from Northern Luzon," *Proceedings of the Biological Society of Washington* 124: 234–247.

Klein, R. G. 2008. "Out of Africa and the Evolution of Human Behaviour," *Evolutionary Anthropology* 17: 267–281.

Kress, J. 1979. "Tom Harrison, North Borneo, and Palawan: A Preliminary Assessment," *Asian Perspectives* 20: 75–86.

Lewis, H., V. Paz, M. Lara, H. Barton, P. Piper, J. Ochoa, T. Vitales, J. Carlos, T. Higham, L. Neri, V. Hernandez, J. Stevenson, E. Robles, A. Ragragi, R. Padilla, W. G. Solheim II, and W. P. Ronquillo. 2008. "Terminal Pleistocene to Mid-Holocene Occupation and an Early Cremation Burial at Ille Cave, Palawan, Philippines," *Antiquity* 82: 318–335

Lucchini, V., E. Meijaard, C. H. Diong, C. P. Groves, and E. Randi. 2005. "New Phylogenetic Perspectives Among Species of South-East Asian Wild Pig (*Sus* sp.) Based on mtDNA Sequences and Morphometric Data," *Journal of Zoology* 266: 25–35.

McBrearty, S., and A. S. Brooks. 2000. "The Revolution that Wasn't: A New Interpretation of the Origin of Modern Human Behaviour," *Journal of Human Evolution* 39: 453–563.

Madulid, D. 1998. "Bases of Biodiversity," in G. Magdaraog, ed., *Environmental and Natural Resources Atlas of the Philippines*. Manila: SEAICE, 42–67.

Maloney, B. K. 1996. "*Canarium* in the Southeast Asian and Oceanic Archaeobotanical and Pollen Records," *Antiquity* 70: 926–933.

Marcone, M. R., Y. Kakuda, F. Jahaniaval, R. Y. Yada, and L. S. Montevirgen. 2002. "Characterization of the Proteins of Pili Nut (*Canarium ovatum*, Engl.)," *Plant Foods for Human Nutrition* 57: 107–120.

Mellars, P. 2006. "Going East: New Genetic and Archaeological Perspectives on the Modern Human Colonization of Eurasia," *Science* 313: 796–800.

Mijares, A. S. B. 2002. *The Minori Cave Expedient Lithic Technology*. *Contributions to Archaeology Series*. Quezon City: University of the Philippines Press.

Mijares, A. S. B. 2005. "Lithic Analysis of Recently Excavated Tabon Cave Flakes," *Proceedings of the Society of Philippine Archaeologists* 2: 15–19.

Mijares, A. S. B. 2008. "The Peñablanca Flake Tools: An Unchanging Technology?" *Hukay, Journal for Archaeological Research in Asia and the Pacific* 12: 13–34.

Mijares, A. S. B. in press. "Human Emergence and Adaptation to an Island Environment in the Philippine Palaeolithic," in Y. Kaifu, M. Izuho, A. Ono, H. Sato, T. Goebel, eds., *Emergence and Diversity of Modern Human Behaviour in Palaeolithic Asia*. College Station: Texas A&M University Press.

Mijares, A. S. B., F. Détroit, P. Piper, R. Grün, P. Bellwood, M. Aubert, G. Champion, N. Cuevas, A. De Leon, and E. Z. Dizon. 2010. "New Evidence for a 67,000-year-old Human Presence at Callao Cave, Luzon, Philippines," *Journal of Human Evolution* 59: 123–132.

Ochoa, J., and P. J. Piper. in press. "Holocene Large Mammal Extinctions in Palawan Island, Philippines," in G. Monks, ed., *Climate Change, Human Response and Zooarchaeology*. *Vertebrate Paleobiology and Paleoanthropology Series*. New York: Springer.

O'Connor, S., R. Ono, and C. Clarkson. 2011. "Pelagic Fishing at 42,000 Years Before the Present and the Maritime Skills of Modern Humans," *Science* 334: 1117–1121.

Oliver, W. L. R., and L. R. Heaney. 1996. "Biodiversity and Conservation in the Philippines," *International Zoo News* 45: 329–337.

Ono, R., S. Soegondho, and M. Yoneda. 2010. "Changing Marine Exploitation During Late Pleistocene in Northern Wallacea: Shell Remains from Leang Sarru Rockshelter in Talaud Islands," *Asian Perspectives* 48: 318–341.

Patole-Edoumba, E. 2002. "L'industrie Lithique Préhistorique de Débitage des Philippines de la Fin du Pleistocène à l'Holocène Moyen." Unpublished Ph.D. dissertation, University of Aix-Marseille I, France.

Patole-Edoumba, E., A. F. Pawlik, and A. S. B. Mijares. 2012. "Evolution of Prehistoric Lithic Industries of the Philippines During the Pleistocene," *Comptes Rendus Palevol* 11: 213–230.

Pawlik, A. F. 2009. "Is the Functional Approach Helpful to Overcome the Typology Dilemma of Lithic Archaeology in Southeast Asia?" *Bulletin of the Indo-Pacific Prehistoric Association* 29: 6–14.

Pawlik, A. F., and W. P. Ronquillo. 2003. "The Palaeolithic in the Philippines," *Lithic Technology* 28: 79–93.

Paz, V. J. 2005. "Rock Shelters, Caves, and Archaeobotany in Island Southeast Asia," *Asian Perspectives* 44: 107–118.

Piper, P. J., F. Z. Campos, and H.-C. Hung. 2009. "A Study of the Animal Bones Recovered from Pits 9 and 10 at the Site of Nagsabaran in Northern Luzon, Philippines," *Hukay, Journal for Archaeological Research in Asia and the Pacific* 14: 47–90.

Piper, P. J., J. Ochoa, V. Paz, H. Lewis, and W. P. Ronquillo. 2008. "The First Evidence for the Past Presence of the Tiger *Panthera tigris* (L.) On the Island of Palawan, Philippines: Extinction in an Island Population," *Palaeoclimatology, Palaeogeography, Palaeoecology* 264: 123–127.

Piper, P. J., J. Ochoa, E. Robles, H. Lewis, and V. Paz. 2011. "Palaeozoology of Palawan Island, Philippines," *Quaternary International* 233: 142–158.

Porr, M., A. S. B. Mijares, A. F. Pawlik, P. J. Piper, and S. Padilla, Jr. 2012. "North of the Southern Arc: A Summary of the 2010 and 2011 Fieldwork Activities," *Australian Archaeology* 75: 110–117.

Rabett, R., J. Appleby, A. Blyth, L. Farr, A. Gallou, T. Griffiths, J. Hawkes, D. Marcus, L. Marlow, M. Morley, Nguyên Cao Tân, Nguyên Van Son, K. Penkman, T. Reynolds, and C. Stimpson. 2011. "Inland Shell Midden Site-Formation: Investigation into a Late Pleistocene to Early Holocene Midden from Tràng An, Northern Vietnam," *Quaternary International* 239: 153–169.

Rohde, R. A. 2005. "Post-Glacial Sea Level Rise," (http://www.globalwarmingart.com/wiki/File:Post-Glacial_Sea_Level.png).

Roskams, S. 2001. *Excavations*. Cambridge: Cambridge University Press.

Sathiamurthy, E., and H. K. Voris. 2006. "Maps of Holocene Sea Level Transgression and Submerged Lakes on the Sunda Shelf," *The Natural History Journal of Chulalongkorn University*, *Supplement* 2: 1–43.

Schiffer, M. B. 1986. "Radiocarbon Dating and the 'Old Wood' Problem: The Case of the Hohokam Chronology," *Journal of Archaeological Science* 13: 13–30.

Skakun, J. D., and A. E. Carlson. 2009. "A Global Perspective on Last Glacial Maximum to Holocene Climate Change," *Quaternary Science Reviews* 29: 1801–1816.

Solheim, W. G. II. 2002. *The Archaeology of Central Philippines: A Study Chiefly on the Iron Age and Its Relationships*. Quezon City: University of the Philippines Press.

Solheim, W. G. II. 2008. "The Pre-Sa Huynh-Kalanay Pottery of Taiwan and Southeast Asia," *Hukay, Journal for Archaeological Research in Asia and the Pacific* 13: 39–66.

Springsteen, F. J., and F. M. Leobrera. 1986. *Shells of the Philippines*. Manila: Carfel Seashell Museum.

Szabó, K. 2009. "Molluscan Remains from Fiji," in G. Clark and A. Anderson, eds., *Early Fijian Prehistory*. Canberra: ANU E Press, 183–211.

Szabó, K., and J. Amesbury. 2011. "Molluscs in a World of Islands: The Use of Shellfish as a Food Resource in the Tropical Island Asia-Pacific Region," *Quaternary International* 239: 8–18.

Szabó, K, H. Ramirez, H. Anderson, and P. Bellwood. 2003. "Prehistoric Subsistence Strategies on the Batanes Islands, Northern Philippines," *Bulletin of the Indo-Pacific Prehistoric Association* 23: 163–172.

Thiel, B. 1990. "Excavations at Musang Cave, Northeast Luzon, Philippines," *Asian Perspectives* 28: 61–81.

Toth, N., and K. Schick. 2009. "African Origins," in C. Scarre, ed., *The Human Past: World Prehistory and the Development of Human Societies*. London: Thames and Hudson, 67–68.

Verheij, E. W. M., and R. E. Coronel, eds. 1992. *Plant Resources of Southeast Asia* No. 2: Edible Fruits and Nuts. Bogor, Indonesia: PROSEA.

Voris, H. K. 2000. "Maps of the Pleistocene Sea Levels in Southeast Asia: Shorelines, River Systems and Time Durations," *Journal of Biogeography* 27: 1153–1167.

de Vos, J., and A. Bautista. 2001. "An Update on the Vertebrate Fossils From the Philippines," *National Museum Papers* 11: 62–105.

Yen, D. E. 1990. "Environment, Agriculture and the Colonisation of the Pacific," in D. E. Yen and J. M. J. Mummery, eds., *Pacific Production Systems. Occasional Papers in Prehistory* 18. Canberra: Department of Prehistory, Research School of Pacific Studies, Australian National University, 258–277.