Mid- to Late Holocene Climate Change and Shoreline Evolution in Tumon Bay, Guam

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Abstract

Archaeological investigations in Tumon Bay, Guam, have provided data documenting age and extent of the mid-Holocene high stillstand and the age and duration of progradation to present shoreline elevation. Radiocarbon ages from coral reef pinnacles in the Tumon Bay fringing reef; from an organic drape over relict late Holocene foreshore ramp; from carbonate cementation zones both above and shoreward from the ramp; and from archaeological features ranging in age from 1,800 ybp to late Latte period, ca. 1000 to 500 ybp, effectively constrain high stand and subsequent progradation and provide a model for interpreting cementation in near-shore contexts. These data conform with expectations of previous geological work in the region and provide new data toward a refined landscape interpretation.

Introduction

Archaeological investigations at the Baba Commercial Center and the Charterhouse – Tropicana projects in Tumon Bay, Guam, have provided data toward a refined understanding of the impact of mid-Holocene high still stands from eustatic sea level rise (Figure 1). At the Baba Commercial Center project a stratum dating from around 2,000 years before present (ybp) had intact hearths, ovens, distinctive pre-latte period pan-shaped pottery, and relict fossil pollen, phytoliths, and starch residues (2). The deposit characterized a backdune habitation site where roasting and cooking of breadfruit, taro, shellfish, marine and estuarine fish and possibly pottery making were practiced. The upper deposits had been removed decades earlier for a proposed development project; nonetheless, over two dozen postholes intrusive into the pre-latte deposit from the latte period were documented, illustrating that the terrain during the latte period from AD 800 to 1500 was higher and dryer than during the older period of settlement.

Archaeological deposits at the Charterhouse – Tropicana project had been mostly disturbed and removed in the 1970s during construction of the Tropicana Hotel. We conducted Ground Penetrating Radar to characterize subsurface deposits and were successful in avoiding cultural resource deposits. Three burials were incidentally impacted but were preserved in place at the edge of the construction zone. Of note in this project is the discovery of a foreshore ramp with a radiocarbon age from an organic sediment ramp of 1900 +/- 40 ybp at 70 meters from the present shoreline, and radiocarbon ages of calcrite deposits onshore from the 1,800 ybp ramp and also seaward, in an area formed after progradation. Other data from Rota and Guam support an earlier date of 3,000 ybp, based on ages of coral pinnacles in backreef terrain (3), illustrating the periodic or punctuated character of the drawdown. Depending on local conditions, or hydro-isostasy, these trends were similar throughout Micronesia and the western Pacific, with eustatic high sea levels of about 1.8 meters (4).

Figure 1: Location of Guam in Marianas Archipelago, Western Pacific
This period of geological change was parallel to dramatic migrations of peoples throughout Southeast Asia, Island Southeast Asia, and Oceania. Evidence of widespread oceanic nomadism is found as early as 4,000 – 5,000 ybp in areas of Southeast Asia and Island Southeast Asia, and by 3,700 to 3,200 ybp Oceanic populations are found on Pacific Islands, including the Lapita cultures of the South Pacific in that era (Figure 2)(5).

The data from these projects have contributed to a model of progradation and terrain evolution following the high stillstand of approximately 5,000 ybp, and demonstrate that the drawdown was not even and gradual, but was punctuated; and that subsurface concretions are context dependent, not age dependent. Along with data from a project at Ritidian Unit, Guam National Wildlife Refuge, we also have learned that Merizo limestone, the beachrock forming during the high still stand, now effectively constrains the earliest possible coastal settlement nearshore. Older settlement, before 4,000 ybp, could only be found offshore or in highland settings away from the coastal strand. Furthermore, from Ritidian we have learned from dating of a variety of contexts that above the Merizo limestone there have been complex patterns of onshore storm surge and colluvial deposition.

These processes of sea level change, calcrite formation, and stochastic effects of storm surge and colluviation both constrain settlement within geological limits and also provide opportunities both for settlement and for contemporary site discovery. For example, the emergence of new coastal land during the period of progradation provided new settlement terrain for late pre-latte and late period habitation; alternatively, older settlement was constrained to higher than present elevations above the shoreline, past and present. Applying these considerations to archaeological survey of coastal terrain provides a model for expectations and for discovery of different ages of settlement, if present.

**Pre-Latte Settlement at the Baba Commercial Center Site, Tumon Bay, Guam**

Rock hearth and oven features were found in at the Baba Commercial Center Site in Tumon Bay, Guam (Figure 3). The upper deposits had been truncated in an earlier development project, but within one meter from the present ground level pre-latte period deposits in the era 500 BC to AD 500 were discovered. The features consisted of numerous hearths of fire-cracked rock, distinctive pan-shaped and incurved “A” type rims, and other artifacts from the period, as well as good preservation of fossil pollen, phytoliths, and starch residue.

These features originally occupied a middle zone on prograded terrain from the highest still stand ca. 4,000 to 5,000 ybp, and the most recent still stand of 1,800 ybp that was documented at the Charterhouse - Tropicana Site to the west, also in Tumon Bay. The features and recovery of pollen, phytoliths and starch residue showing taro, breadfruit, etc. along with a variety of shellfish and both reef and pelagic fishes as well as turtle demonstrate a very robust lifeway. Most sites

**Figure 2: Oceanic migration and earliest known settlement dates.**

**Figure 3: Baba Commercial Center in Tumon, Guam, showing 1,800 ybp hearths and ovens exposed in backdune terrain from that period.**
from this period are situated in backdune or nearshore terrain in Guam, though a few early dates from interior Guam demonstrate highland settlement as well. Discovery may be more problematic in interior terrain as episodic deposition and degradation may have led to burial or scouring of the landscape. However, near shore terrain sites have been found intact. The radiocarbon ages at the Baba Commercial Center from hearths demonstrate settlement from 500 BC to AD 500 consistent with other data on this period of settlement in Guam. Posthole ages post-AD 500 appear to be intrusive from early late period settlement in truncated deposits (Figure 4).

Figure 4: Radiocarbon chronology for Baba Commercial Center Site.

**Charterhouse – Tropicana Site and Evidence of 1,800 ybp Still Stand**

A relict foreshore ramp was discovered in a backhoe trench during testing of Ground Penetrating Radar anomalies (1). The ramp was 70 meters shoreward from the present shoreline and was buried about one meter deep. An organic drape of 1 – 4 cm thickness was sampled for a radiocarbon age that was determined to be 1900 +/- 40 ybp, conventional age.

The ramp and drape were designated Layer II-c, sloping downward toward the shoreline (Figures 5 – 8). The seaward-dipping slope reflects the position of a former foreshore ramp that was stable probably for a very brief time interval when the organic horizon began to form. No artifacts or midden were observed in Layer II-c. Within Test Trench 6, the two samples of charcoal flecks were retrieved from Layer II-c, and they yielded largely consistent radiocarbon dates of cal. AD 120-350 (Beta-239574) and cal. AD 20-230 (Beta-243733). The dating results overlap significantly in the range of AD 120-230.

The date range of approximately AD 120-230 for the incipient organic horizon indicates approximately the estimated end of a period of sea-level drawdown, but substantial beach progradation must have occurred between then and now. Since the last time when this very thin organic layer existed on a relict foreshore, beach progradation has exceeded 70 m until the formation of the present-day foreshore at this location along Tumon Bay.

**Calcic Horizons at Charterhouse – Tropicana and Ritidian Sites**

In Backhoe Trench 9, excavated inshore from the 1,800 ybp foreshore ramp, Layer II-d refers to a layer of calcrite, documented around 1.3 m depth throughout the project area in locations where prior construction disturbance did not occur to that depth. The hardening is a form of cementation, caused by settling of carbonates in water into the sand, likely a combination of: a) downward drainage of rain water; and b) upward-wicking during evaporation from the underlying water table. In this model, the cementation must have occurred significantly later than the original deposition of the sand itself.

Carson (6) described the same type of hardened or cemented sand layer at the Unai Bapot archaeological site in Saipan:

The cementation occurred after the deposition of artifacts and midden in the original sandy matrix, or else the objects could not have been encrusted within the cemented material. At Unai Bapot, the sand
appears to have hardened due to upward-wicking and evaporation of carbonate-rich water and precipitation of carbonates settling into this layer. These processes would have occurred some time after … [the original sandy layer] was buried beneath some centimeters of later-deposited sand, presumably when the vicinity was a stable backbeach flat.

Two radiocarbon dates were obtained for samples of the hardened sand in Layer II-d, aiming to clarify the relationship between the original deposition of the sand and the later hardening. From Test Trench 9 in the landward portion of the subject property, radiocarbon dating indicates original deposition around cal. 840-500 BC (Beta-239575). From Excavation Block B in the seaward portion of the subject property, radiocarbon dating indicates original deposition around cal. AD 670-950 (Beta-246698)(Figure 10) (Figure 11). The results show that the original sand deposition was much earlier in the landward portion of the project area (Test Trench 9) and much later in the seaward portion (Excavation Block B), although the same cementation process occurred around the same depth at a later time in both cases.

Based on these latest findings, the process of sand cementation appears to have depended on the depth below ground surface at a time somewhat later than the original deposition of the sand buried in Layer II-d. For example, the present case shows that the cementation occurred around the same depth of 1.3 m in both landward (older) and seaward (younger) deposits. The regularity of depth very likely relates to the depth of the affected sandy material in relation to both the overlaying ground surface and the underlying water table, wherein moisture settled via downward drainage and upward-wicking evaporation. The repeated settling of moisture, especially if carbonate-rich, contributed to the hardening of the sand at a consistent depth interval. The affected depth interval is around 1.3 m in the present case, but it may be higher or lower in other localities with a different configuration of pertinent controlling factors.

The hardened or cemented sand layer perhaps more properly may be termed “calcrete” or a “calcic horizon.” This terminology refers to cementation of the sand due to carbonate-rich water settling repeatedly into a certain depth or horizon, as described above. The cementation occurs at a specific depth in any given locality, regardless of any variation in age of the original deposits.

The calcrete or calcic horizon possesses many of the same characteristics as beach rock, but the timing of cementation in this case must have occurred significantly later after the sand had been buried to an appropriate depth.

Figure 6: Terrain model for Charterhouse – Tropicana Project showing relict foreshore and calcic horizons inshore (900–750 BC) and in prograded terrain (AD 800–1000). Schematic view to East.

Conceivably, archaeological materials and habitation layers may be sealed within or beneath this type of hardened sand layer as at Unai Bapot in Saipan. In contrast, most beach rock formations tend to be much older than any possible archaeological materials in the Marianas region.

A radiocarbon age of cal. 840-500 BC was determined for a sample of calcrete of Layer II-d at 1.3 m depth in the landward (south) portion of the subject property. This result indicates that any older habitation zones, campsites, or other land use areas must have been slightly further landward (south). The possible surviving remnants of any such activities likely would have been buried about 1 to 1.5 m beneath the present-day Pale San Vitores Road in this portion of Tumon, but construction of the road and underground utilities already may...

Figure 7: Stratigraphy of Backhoe Trench 6 at Charterhouse – Tumon project area showing foreshore ramp (view to east).
Calcic Horizons and Storm Surge Impacts at Ritidian Unit, Guam Wildlife Refuge

Additional data gathered at the Ritidian Unit, Guam Wildlife Refuge during MARC archaeological field school research contributes to shoreline terrain model with additional dates on calcic horizons as well as demonstration of patchy deposition from history of storm surge on an exposed coastline. Excavations at Ritidian, at the northern end of Guam, revealed buried cultural deposits separated by thick layers of culturally sterile storm surge sand and other natural beach deposits. The oldest cultural deposit, dated approximately 1200 – 1400 B.C. included very thin redware pottery, shell, fish bone, and soot deposited directly over a coral reef deposit dated about 2200 – 2000 B.C. A later occupation layer also containing thin redware pottery was dated AD 800 – 1000.

A calcic horizon had formed within the second-oldest cultural deposit at Ritidian, but the oldest deposit in looser beach sand beneath the calcrite and directly above the old coral reef. Like at the Unai Bapot site at Saipan, this example from Ritidian demonstrates that ancient cultural deposits potentially can be sealed within and beneath calcrite. The date of 2200 – 2000 B.C. for the underlying coral reef indicates that sites of this age or older cannot be found in the coastal zone here, unless they have become sealed within or beneath the ancient coral growth. This finding also highlights the possibility of inter-tidal or shallow sub-tidal site contexts that will require new research approaches.
Summary and Synthesis

Based on data from recent projects in Guam, a model may be proposed for the sea-level drawdown and associated beach progradation. The period of high sea stand has been documented as early as 5,000 ybp. By 4,000 ybp radiocarbon ages of coral reef pinnacles document this highest sea level before its decline beginning about 3,000 ybp, or 900 BC (3). The early period of sea-level fall started around 900 BC, followed by a period of an additional rapid fall immediately after AD 120-230. A number of short-lived “still stands” of sea level may have occurred, for example around AD 120-230. During the later period of apparently more rapid sea-level fall, larger numbers of people living in Guam likely contributed to other factors of 950 – 750 BC, or 2970 +/- 50 ybp conventional radiocarbon age, while those landward from the 1,800 ybp shoreline were formed in the period 950 – 750 BC, or 2970 +/- 50 ybp conventional radiocarbon age, which are short-lived and suitable for radiocarbon dating (3). These dates are consistent with the findings of other studies in the region, including the Ritidian Unit, Guam National Wildlife Refuge. Based on data from these recent projects in Guam, a model may be proposed for the sea-level drawdown and associated beach progradation. The period of high sea stand has been documented as early as 5,000 ybp. By 4,000 ybp radiocarbon ages of coral reef pinnacles document this highest sea level before its decline beginning about 3,000 ybp, or 900 BC (3). The early period of sea-level fall started around 900 BC, followed by a period of an additional rapid fall immediately after AD 120-230. A number of short-lived “still stands” of sea level may have occurred, for example around AD 120-230. During the later period of apparently more rapid sea-level fall, larger numbers of people living in Guam likely contributed to other factors of 950 – 750 BC, or 2970 +/- 50 ybp conventional radiocarbon age, while those landward from the 1,800 ybp shoreline were formed in the period 950 – 750 BC, or 2970 +/- 50 ybp conventional radiocarbon age, which are short-lived and suitable for radiocarbon dating (3). These dates are consistent with the findings of other studies in the region, including the Ritidian Unit, Guam National Wildlife Refuge.

Our investigations demonstrate the patchiness and unpredictability of redeposition outside the constraints of beachrock or calcrete, so that other markers must be interpreted as components and processes of the historical evolution of shorelines in the region.

![Figure 12: Model of Coastal Evolution in Ritidian Unit, Guam National Wildlife Refuge.](image)

demonstrates that the calcic horizons were formed some time later than the original deposition of the sand, so that archaeological materials and cultural deposits were buried within and beneath the hardened sand wherever it occurs. The calcite formation depends on depth and local hydrology, and is not a uniform marker of a same-age deposit. This model hopefully will help to improve future research about ancient coastal sites throughout the Marianas region. The calcic horizon constrains stratigraphic horizons, and its depth and distance from shore can be useful as a discovery tool for localized same-age or earlier archaeological deposits which are protected in the deposits from storm surge or other redeposition.

On the other hand, in contexts above the calcrete, shorelines in Guam are quite dynamic. As demonstrated at Ritidian, recent age deposits often appear at depths of 1.0 to 1.5 meters below surface while very old deposits can be found near the ground surface. Other dates from excavation of a Spanish contact period Latte period feature with wrought iron and Ming period Chinese porcelain demonstrate this dynamism. Radiocarbon dates from within 20 cm below ground surface in the range of AD 400 – 600 contrast with the artifact assemblage, and also from nearby late Latte period deposits beneath a burial and one meter deep which are in the range of AD 1400 – 1600. A complex mosaic of deposits of various ages at varying depths is accounted for by the severe impact of storm surge deposits in the Ritidian environment (3).

The documentation and dating of the hardened sand or calcrete in Layer II-d marks a major milestone in geoarchaeological research in the region. The present work
Figure 13: Radiocarbon ages of deposits at Ritidian Unit.

References Cited


