Evolution of an Austronesian Landscape: The Ritidian Site in Guam

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ABSTRACT

Geoarchaeological research reveals 3500 years of landscape ecology and evolution at the Ritidian Site in Guam, Mariana Islands. This example illustrates the first time when an Austronesian group lived in an extremely remote and small island setting. An integrated natural-cultural history of the landscape explores the unique and isolated habitat of the first settlement and its evolution through subsequent centuries.

Key words: Pacific geoarchaeology, landscape, ecology, Guam, Mariana Islands

INTRODUCTION

A case study in the Mariana Islands examines long-term evolution of an isolated Austronesian landscape, witnessed in the intimately related natural and cultural history. The specific case study is at the Ritidian site in northern Guam, where intensive research 2006–11 now enables a high-resolution landscape chronology spanning the last 3500 years. This unique example supports deeper understanding how Austronesian groups eventually colonized the farthest reaches of the remote Pacific and co-evolved with their changing landscape ecologies.

The isolated character of the Marianas guarantees an Austronesian origin for initial adaptations and subsequent landscape evolution. By comparison, roughly contemporaneous Lapita colonists in the Bismarcks and Solomons interacted significantly with long-established Papuan communities (Green 2000; Spriggs 1997; Summerhayes 2000). The Marianas case therefore offers the opportunity to examine what happened in a solely Austronesian cultural setting.

The isolation of the Marianas additionally is important for understanding the first successful migration of people across the Asia-Pacific frontier, for the first time settling in completely new territory and in a remote Pacific Island setting (Figure 1). When first colonized 3500 years ago, these islands were more than 2000 km distant from any contemporaneous populated area (Hung et al. 2011). By comparison, Lapita groups eventually

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crossed a maximum 900 km into the islands of Remote Oceania such as Vanuatu, New Caledonia, Fiji, Tonga, and Samoa 3100–2800 years ago (Burley and Dickinson 2001; Nunn 2007; Sand 1997), distinctively later and over a shorter distance than for Marianas colonization.

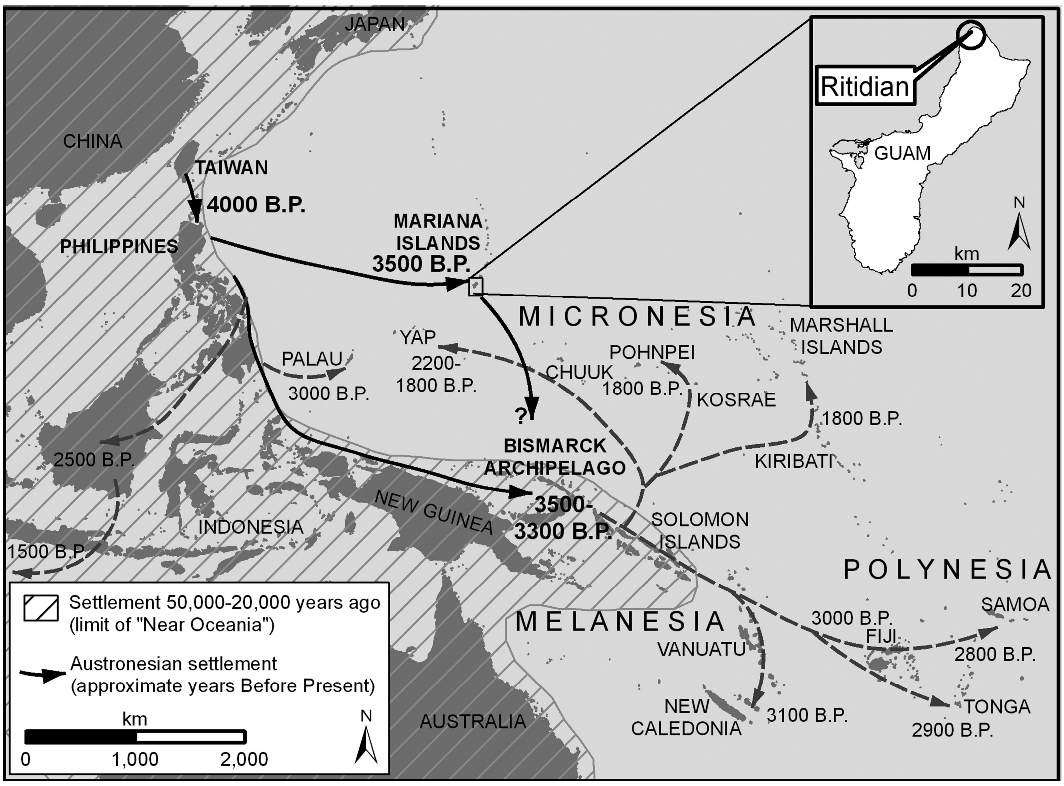

Fig. 1：Map of Asia-Pacific region, with inset showing Ritidian in Guam, southernmost of the Mariana Islands.

The small and remote context of the Marianas further becomes advantageous for maximizing the realistic material sampling of environmental and archaeological records. The physical evidence is more confidently inventoried here than in a larger land mass or more diverse cultural area. Moreover in the fragile ecosystems of remote small islands, the impacts by people tend to be exaggerated and more easily detectable.

The 3500-year record in the Marianas enables deep examination of landscape ecology and evolution, so far not possible in other Remote Oceanic islands with shorter chronologies. The longer time-range in the Marianas accommodates a variety of known changes in the world’s natural history, as well as regional and localized environmental and cultural processes. Intensive multi-year research at the Ritidian site has been most productive for developing an ideal model case study.

This research integrates multiple lines of evidence from radiocarbon dating, terrain geomorphology, artifacts, and faunal remains into a single chronology at the Ritidian site in northern Guam. First, the 2006–11 Ritidian project is described, and a basic outline is presented of the landscape ecology and evolution. Next, each line of evidence is presented, followed by a synthesis.

RITIDIAN RESEARCH PROJECT

Ritidian holds one of the hidden treasures of Guam (Figure 2), where a protected ecosystem includes a clear lagoon, stunning white-sand beach, dense forest, and dramatic limestone escarpment. The area today is preserved as the Ritidian Unit of Guam National Wildlife Refuge (GNWR), managed by US Fish and Wildlife Service (USFWS). Sustained research 2006–11 supplied detailed information for a synthesis of the complex natural-cultural history.

Fig. 2：Photograph overview of Ritidian, 2006.

Ritidian contains several megalithic *latte* sites (Osborne n.d.; Reed 1952; Reinman 1977), pertaining to the last indigenous village settlement prior to re-location of the native population by A.D. 1700 (Carson 2012a). Nearly the entire terrain surface is covered by varying densities of artifacts and midden of the *latte* period, dating potentially as early as A.D. 900–1000 (Kurashina 1990). Additional studies 2008–10 focused on *latte* household organization (Bayman et al. 2012) and Spanish colonial contact of the late 1600s (Jalandoni 2011).

The sustained research 2006–11 revealed a much deeper prehistory than the surface-accessible *latte* period, significantly pre-dating the development of the landscape as seen today (Carson 2011). The oldest buried site deposit was confirmed as nearly 3500 years old (Carson 2010), among the earliest in the Mariana Islands as a whole (Carson 2008). This older cultural chronology was coordinated with natural history sequence for a fuller understanding of landscape evolution at Ritidian.

The research program entailed exploratory survey and 69 geoarchaeological test excavations (Figure 3). Landscape evolution was traced through a relative chronology of sedimentary layers and archaeological deposits, building a palaeoterrain model (Carson 2011). Additional environmental information came from close study of the shellfish records and other faunal remains (Carson 2012b). High-precision radiocarbon dating provided absolute chronological control of key points in the landscape sequence (Carson 2010).

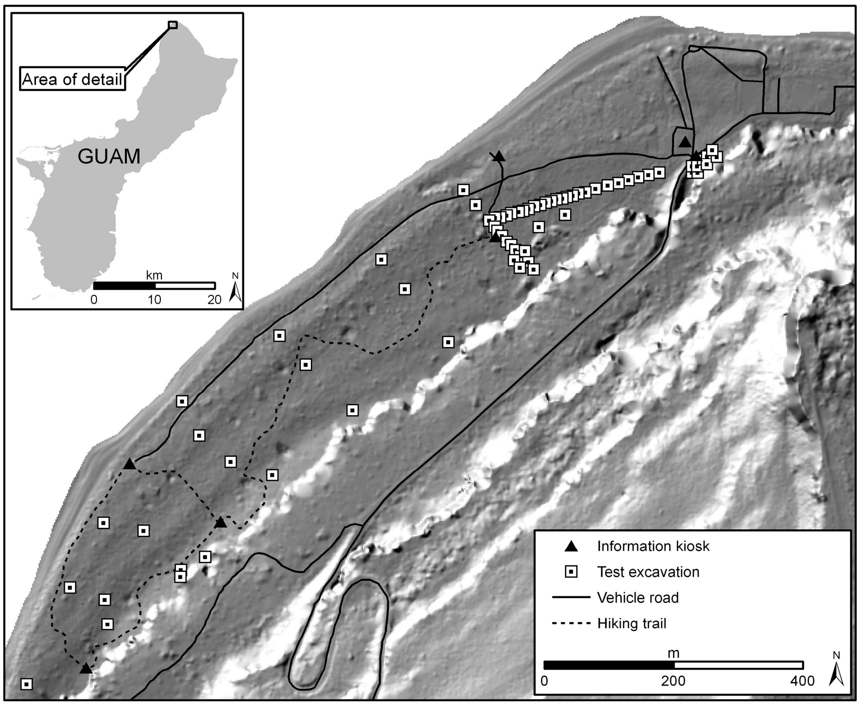

Fig. 3：Ritidian 2006–11 study area, noting locations of test excavations. Individual test pit numbers and material findings intentionally are removed from this detailed scale of map, in accordance with site-protection measures of the US Archaeological Resource Protection Act (ARPA).

LANDSCAPE ECOLOGY AND EVOLUTION

The Ritidian landscape chronology coordinates evidence of sea-level history, terrain formation, faunal remains, number and size of habitation sites, and artifact associations (Figure 4). The different lines of evidence in total reflect the natural and cultural components of a holistic landscape. These components inter-related in complex ways over a long-term sequence, mutually affecting each other while the landscape evolved as a whole.

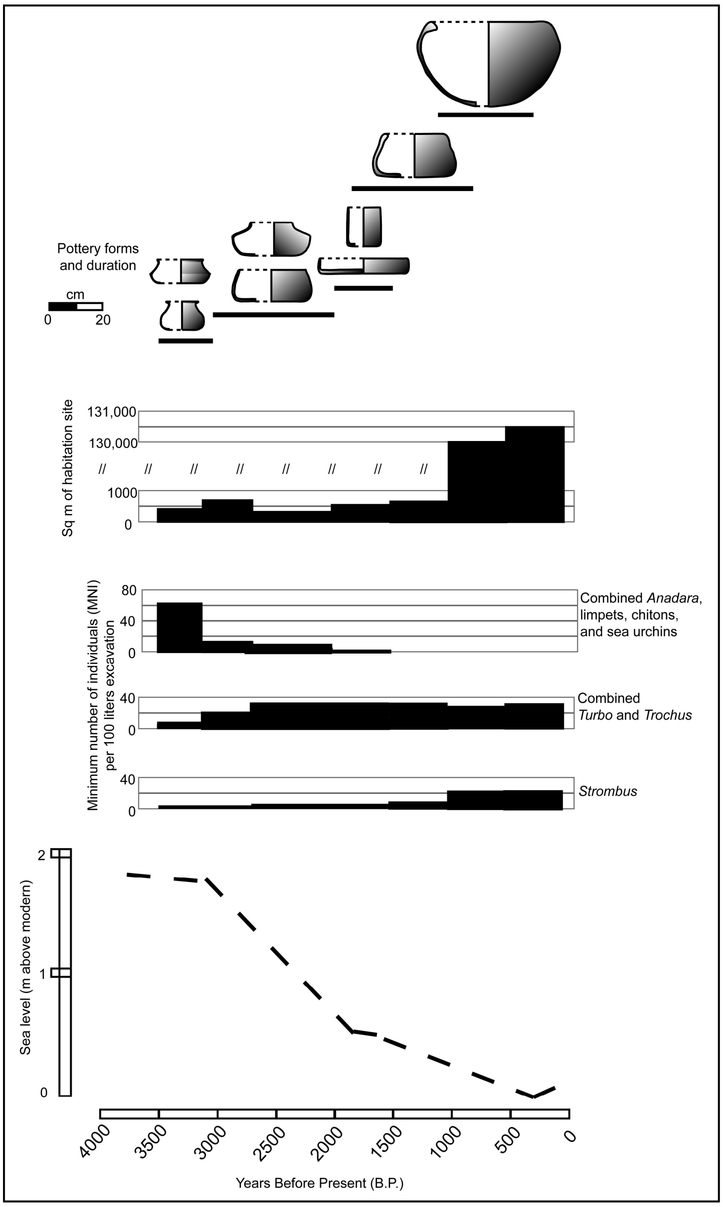

Fig. 4：Integrated landscape chronology of Ritidian.

The established field of *landscape ecology* stresses the inter-relations of individual parts within an environment (Turner et al. 2001). Typically, the analysis is synchronous within a singular defined time-range or modern setting, thus allowing close observation of living details otherwise not possible in archaeological studies of remnant material records. The relationships between landscape components are expressed in spatial configurations and functional operations, creating in essence a structure or identity of the landscape (Cumming 2011), subject to change over time as in the Ritidian example.

The Ritidian research emphasizes the chronological dimension of landscape, thereby expanding the usual short-term view of landscape ecology for a more long-term view of landscape evolution. This perspective parallels archaeological pursuits of *historical ecology* (Crumley 1994), here with a focus on the landscape itself, perhaps familiar to geoarchaeologists working to extend a *human ecology* perspective (Butzer 1982; Wilson 2011). As shown here, the landscape as a whole can be studied for each separate time interval. Evolution or co-evolution of inter-related elements can be examined best in a long-term perspective, as in the 3500-year record at Ritidian.

The Ritidian example draws on material geoarchaeological evidence related to the past landscape and how it evolved, as summarized in Figure 4. Each line of evidence is reviewed, followed by a comprehensive chronological synthesis. This integrated natural-cultural history then can support discussion of how the landscape evolved or more precisely how its inter-related components co-evolved.

RADIOCARBON DATING

The chronological sequence is based primarily on relative ordering of stratigraphic layers, with radiocarbon dating of key components. The radiocarbon dating supplements the overall sequence with absolute calendar dates. The complete radiocarbon results are summarized in Table 1 for reference.

The dating shows first settlement in one small area nearly 3500 years ago, but the most extensive habitation occurred within the last 1000 years. The settlement growth was more than a simple linear progression reflecting steady population increase. Rather, it involved fluctuating relations between resident groups and the changing natural habitat, in conjunction with social change.

One crucial technical advance in the radiocarbon dating was calculation of a local marine reservoir correction (ΔR) for *Anadara antiquata* shells, paired with carbonized coconut nutshells (Carson 2010). In two separate pairings, the individual ΔR results significantly overlapped with one another, giving a confident average (mean) ΔR of -44±41. These shellfish were an important food resource during the early settlement period, and they often were discarded in clearly cultural contexts within site middens. The bivalves lived in confined ranges of muddy or swampy environments with little movement, so the ΔR does not significantly vary from one specimen to another. By comparison, other types of shells, such as *Conus* and *Cypraea*, have proven unreliable due to the migrating nature of these gastropods over reefs of variable ages.

A second important advance was for direct dating of freshly deposited *Halimeda* sp. algal bioclasts that comprise a major material component of certain coastal landforms like at Ritidian (Carson and Peterson 2012). *Halimeda* shed their bioclasts every 2–12 months, so beds of the bioclasts can accumulate quickly inside a protected lagoon as at Ritidian. These bioclasts erode quickly into smoothed edges, so finding them in intact condition signifies fresh deposition in primary context.

The ability to date *Anadara* shells and *Halimeda* bioclasts greatly strengthened this research program, especially at Ritidian with a sequence of coastal landforms generally lacking datable charcoal in the earliest layers. The dating results must be acknowledged as requiring attention to their context and associations for proper understanding of the chronological sequence.

PALAEOTERRAIN MODELING

The Ritidian research contributed significantly to an island-wide reconstruction of Guam's palaeohabitat (Carson 2011), depicting the terrain during first human settlement 3500–3000 years ago (Figure 5). Initial colonization occurred long prior to the development of the broad sandy beaches and coastal plains seen today. The colonists targeted specialized shoreline niches, but this way of lifeeventually could not be sustained after substantial environmental change, cultural impacts, and population growth.

Most important for the palaeoterrain modeling, ancient sea level stood about 1.8 m higher during the first Austronesian colonization prior to 3000 years ago (Dickinson 2000, 2001, 2003). These conditions did not last for long after initial settlement, followed by sea- level drawdown 3000 through 1800 years ago. Excavations in some cases encountered ancient coral reef layers, now deeply buried, where the depths and dates verified the regional sea-level chronology. Others found evidence of ancient lagoonal environments, where again the depths and dates were important for reconstructing the natural history sequence.

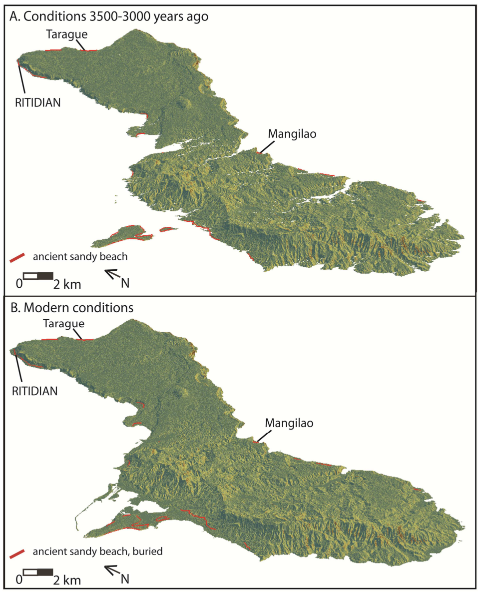

Fig. 5：Guam-wide terrain model: A. 3500–3000 years ago; and B. modern conditions. Locations are shown for confir-med early-period settlement sites. Other buried beach deposits have not yet shown evidence of earliest settlement.

Table 1：Ritidian radiocarbon dating summary.

Provenience	Beta-######	Material	Measured Age (years B.P.)	$^{13}C/^{12}C$ Ratio (‰)	Conventional Age (years B.P.)	Marine Reservoir Correction (ΔR)	2-Sigma Calibration (years B.P)
Fenceline Pit 35							
98-105 cm, beach-ridge habitation	239577	Carbonized coconut endocarp fragment	2820 ± 40	-25.4	2810 ± 40	Not applicable	3059-3053 (0.5%); 3031-3014 (1.5%); 3005-2792 (93.5%)
98-105 cm, beach-ridge habitation; testing for possible ΔR	239576	*Cellana* sp. shell	5340 ± 40	+3.9	5180 ± 40	2683±58	3110-2745 (95.4%)
105-110 cm, beach-ridge habitation; testing for possible ΔR	239578	*Anadara* sp. shell	5340 ± 40	+1.5	3140 ± 40	13±58	3110-2745 (95.4%)
110-120 cm, natural surge layer	303808	*Acropora* sp. branch coral	2870 ± 30	-1.1	3260 ± 30	-44± 41	3309-2991 (95.4%)
250-260 cm, food discard during earliest cultural activity	253681	*Anadara* sp. shell	3030 ± 40	-0.7	3430 ± 40	-44 ± 41	3499-3205 (95.4%)
255-260 cm, freshly deposited during earliest cultural activity	253682	*Halimeda* sp. algal bioclasts	2980 ± 40	+5.3	3480 ± 40	-44 ± 41	3532-3238 (95.4%)
262-263 cm, pre-cultural natural surge	303807	*Acropora* sp. branch coral	3390 ± 30	-3.0	3750 ± 30	-44 ± 41	3878-3593 (95.4%)
260-265 cm, pre-cultural reef growth	253683	*Heliopora* sp. coral	3610 ± 50	+4.4	4100 ± 50	-44 ± 41	4404-4017 (95.4%)
Fenceline Pit 34							
150-155 cm, non-cultural lagoonal deposit	239579	*Halimeda* sp. algal bioclasts	3140 ± 40	-3.2	3500 ± 40	-44 ± 41	3586-3305 (95.4%)

Provenience	Beta-######	Material	Measured Age (years B.P.)	$^{13}C/^{12}C$ Ratio (‰)	Conventional Age (years B.P.)	Marine Reservoir Correction (ΔR)	2-Sigma Calibration (years B.P)
Walkway Pit 2							
33 cm, widespread intensive habitation	263447	Carbonized coconut endocarp fragment	780 ± 40	-24.5	790 ± 40	Not applicable	776-669 (95.4%)
92 cm, cliff-base habitation	263448	Carbonized coconut endocarp fragment	2500 ± 40	-24.5	2510 ± 40	Not applicable	2744-2459 (94.3%); 2386-2370 (1.1%)
90-100 cm, cliff-base habitation; testing for possible ΔR	263449	*Anadara* sp. shell	2370 ± 40	+2.1	2810 ± 40	-103±59	2842-2454 (95.4%)
126 cm, cliff-base habitation	263450	Carbonized coconut endocarp fragment	2490 ± 40	-24.0	2510 ± 40	Not applicable	2744-2459 (94/3%); 2386-2370 (1.1%)
128 cm, cliff-base habitation; testing for possible ΔR	263451	*Conus* sp. shell bead artifact	2710 ± 40	+1.5	3180 ± 40	267±59	2842-2454 (95.4%)
Trail Location 1							
25-28 cm, widespread intensive habitation	303809	Charcoal	920 ± 30	-23.9	940 ± 30	Not applicable	926-790 (95.4%)
35-40 cm, cliff-base habitation	303810	Charcoal	1980 ± 30	-25.2	1980 ± 30	Not applicable	1995-1872 (95.4%)
65-70 cm, pre-cultural lagoonal deposit	303811	*Halimeda* sp. algal bioclasts	3630 ± 30	+2.6	4080 ± 30	-44 ± 41	4365-4029 (95.4%)
Trail Upper Cave							
5-10 cm, ritual use of cave	303812	Organic sediment	910 ± 40	-25.3	910 ± 40	Not applicable	919-740 (95.4%)
30-35 cm, limited cave use	303813	Organic sediment	1880 ± 40	-25.0	1880 ± 40	Not applicable	1897-1715 (95.4%)
30-35 cm, limited cave use	303814	Organic sediment	1710 ± 40	-27.4	1710 ± 40	Not applicable	1709-1535 (95.4%)

Provenience	Beta-######	Material	Measured Age (years B.P.)	$^{13}C/^{12}C$ Ratio (‰)	Conventional Age (years B.P.)	Marine Reservoir Correction (ΔR)	2-Sigma Calibration (years B.P)
Trail Lower Cave							
15-20 cm, ritual use of cave	303815	Charcoal	340 ± 30 BP	-27.9	290 ± 30	Not applicable	458-348 (64.5%); 335-288 (30.9%)
30-35 cm, ritual use of cave	303816	Charcoal	520 ± 30 BP	-25.8	510 ± 30	Not applicable	622-609 (4.5%); 555-505 (90.9%)
45-50 cm, ritual use of cave	303817	Charcoal	520 ± 30 BP	-24.0	540 ± 30	Not applicable	634-596 (29.6%); 562-513 (65.8%)
75-80 cm, pre-dating cultural activity	303818	Organic sediment	5560 ± 40	-22.5	5600 ± 40	Not applicable	6452-6360 (95.4%)
75-80 cm, pre-dating cultural activity	303820	*Halimeda* sp. algal bioclasts	3790 ± 30	+0.1	4200 ± 30	-44 ± 41	4501-4198 (95.2%); 4192-4189 (0.2%)
80-82 cm, pre-dating cultural activity	303819	Beachrock bioclasts	4210 ± 30	+1.0	4640 ± 30	-44 ± 41	5059-4800 (95.4%)
Emergency Recovery Pit 2							
20-25 cm, widespread intensive habitation	247659	Carbonized coconut endocarp fragment	240 ± 40	-25.0	240 ± 40	Not applicable	430-358 (14.5%); 331-266 (40.1%); 218-142 (31.3%); 23-4 (9.5%)
80 cm, widespread intensive habitation	247660	Carbonized coconut endocarp fragment	340 ± 40	-24.4	350 ± 40	Not applicable	495-313 (95.4%)

All calibrations are at 2-Sigma (95.4%), using OxCal version 4 (Bronk Ramsey 2009). Charcoal and organic sediments were calibrated with INTCAL09 data-set, and marine specimens were calibrated with MARINE09 data-set (Reimer et al. 2009). Local marine reservoir effect (ΔR) follows calculations specifically for the Ritidian site (Carson 2010).

Intensive research made the Ritidian case the most detailed of the Guam-wide study (Figure 6). The terrain model was adjusted for each time interval, accounting for the measured dates and depths of ancient land surfaces throughout the given sequence. The archaeological findings then could be contextualized within this larger model.

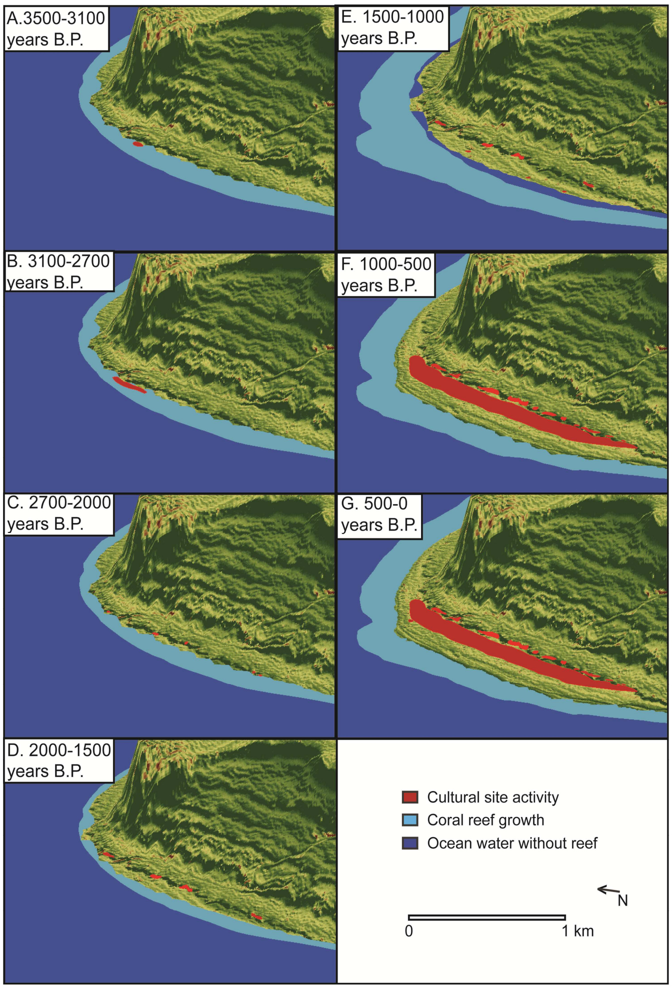

Fig. 6：Riditian palaeoterrain sequence.

ARTIFACT CHRONOLOGY

The Ritidian pottery and other artifacts are consistent with the overall Marianas regional chronology. The earthenware artifacts are the most sensitive for chronological change, and their abundant broken pieces conveniently support temporal estimates for each site layer. At least a few stone and shell artifacts additionally are diagnostic of certain time periods. Features such as stone-column house posts, stone mortars, and rock art mostly relate to the *latte* period 1000–300 years ago.

The pottery shows a clear change over time, beginning with thin-fine red-slipped small bowls and jars, shifting to large flat-bottomed shallow pans, and ending with coarse-thick large vessels (Figure 7). The very thin-walled and finely made pottery of the earliest settlement period 3500–3100 years B.P. was not sustained for more than a few centuries. Slightly thicker and coarser wares began production about 3100–3000 years ago, marking the beginning of a trend of increasingly thicker, coarser, and larger vessels over time. The most exceptionally large vessels were produced only much later, within the last 1000 years.

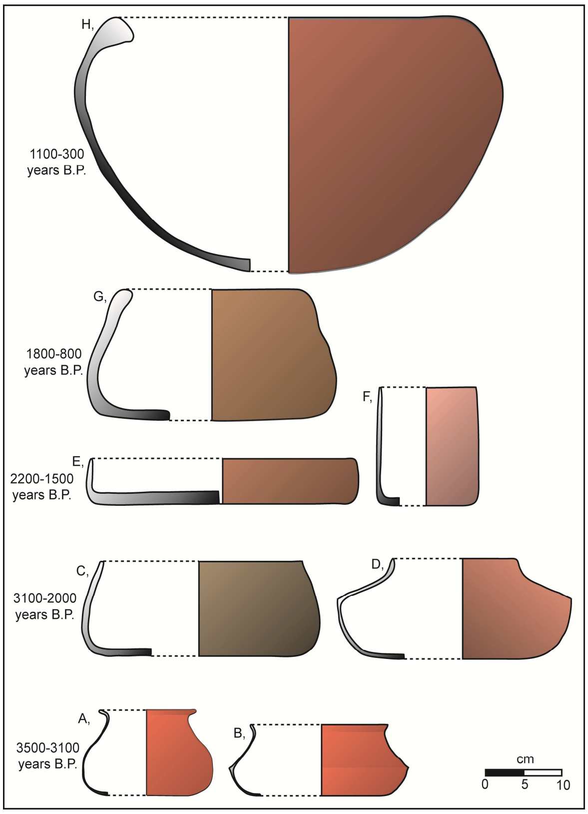

Fig. 7：Pottery chronology at Ritidian.

The overall trends in pottery-making suggest an increasing scale of production, as well as larger serving-size. The vessels likely were produced more quickly for more people. Another possibility involves a shift in practical daily use, at first involving single-serving vessels in the earlier periods, then accommodating larger communal serving of larger households in later periods. The outcomes are most pronounced in the very large vessels produced within the last 1000 years, coinciding with the most impressively large habitation sites and presumably a regional population growth (see Figure 4). This change further correlates with a shift in shellfish gathering, introduction of rats for the first time, and possible decline in local avifauna as discussed in the next section of “Faunal Records.” These factors did not co-occur entirely by accident, but they reveal a complex set of inter-relations.

Adzes and flaked debitage at Ritidian include both volcanic stone and *Tridacna* (giant clam) shell (Figure 8-A and -B). Both were used throughout the chronological sequence, and both show signs of local production and maintenance at Ritidian. In addition, many flakes may have been used as cutting or slicing tools, especially those made of chert or other cryptocrystalline.

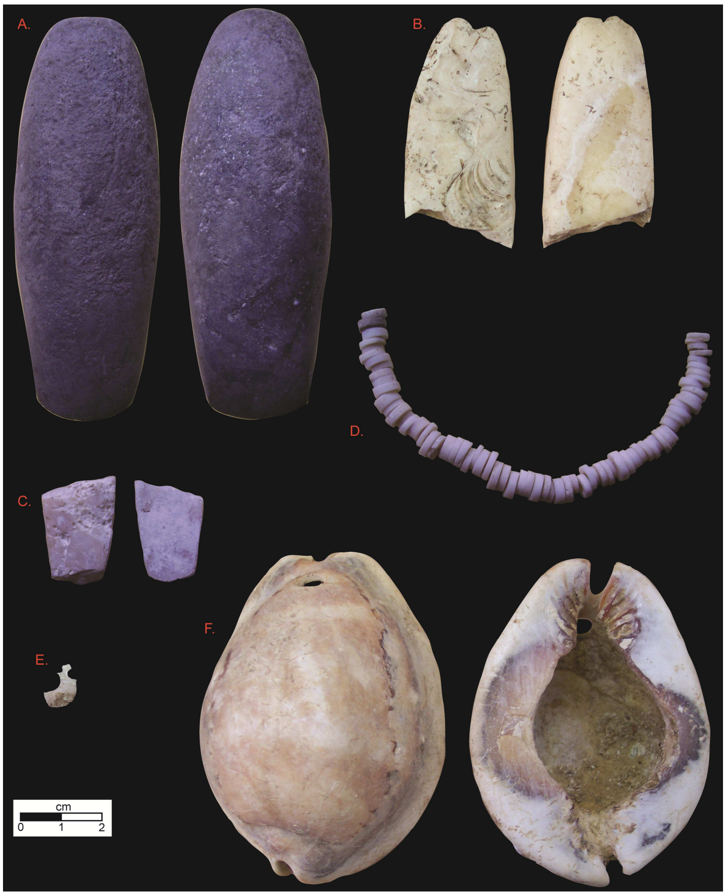

Fig. 8：Examples of stone and shell artifacts at Ritidian. A. Stone adze or chisel, 1000–500 years B.P.; B. *Tridacna* sp. shell adz, broken, 1000–500 years B.P.; C. Fragment of probable fish-trolling lure, about 3000 years B.P.; D. Set of *Conus* sp, shell beads, 2700–2500 years B.P.; E. Incomplete fish-hook of *Isognomon* sp. shell, 500–300 years B.P.; F. Worked *Cypraea* sp. shell portion of octopus lure, 500–300 years B.P.

Shell was the preferred material for fashioning fishing gear and personal ornaments. *Isognomon* shell is most common, especially in workshop debitage, valued for its nacreous qualities and its easily workable flat surfaces (Figure 8-E). A rare fragment of a probable trolling lure represents one of the few known specimens from a context about 3000 years old (Figure 8-C). A set of 71 of *Conus* shell beads was found at one location dated about 2700–2500 years ago (Figure 8-D). A worked piece of *Cypraea* shell resembles one component of a typical Oceanic octopus lure, in this case dating 500–300 years ago, just prior to Spanish colonial occupation (Figure 8-F).

The *latte* period, approximately 1000 through 300 years ago, is named after the megalithic *latte* stone ruins of house-posts topped with capitals or cap-stones (Figure 9). Other stone features of this era included stone mortar basins called *lusong*, often carved into the limestone bedrock along the cliff-base (Figure 10).

Fig. 9：Photograph of *latte* ruins at Ritidian. Scale bar is in 20-cm increments.

At least four caves at Ritidian contain pictographs of hand-prints, male and female figures, and other shapes, made in red, black, and white pigments (Figure 11). Direct dating has not yet been attempted of the pigments, but the cultural deposits inside these caves are constrained within the last 2000 years and most intensive within the last 500 years. Images of headless bodies perhaps memorialize post-mortem head-removal, known ethnohistorically in the Marianas (Cabrera and Tudela 2006). The hand-prints imply markings by individual participants in rites of passage.

Fig. 10：Photograph of *lusong* mortar stone at Ritidian. Scale bar is in 20-cm increments.

Several artifacts and features relate to the Spanish colonial period, most intensive at Ritidian during the late A.D. 1600s. A Jesuit missionary outpost was established at Ritidian during this time, today found only in scattered subsurface remnants (Jalandoni 2011). Surface-visible ruins include stone-faced terraces and stone-lined wells (Figure 12). Asian and European goods were imported during this period, most obvious in the form of ship’s nails, glass beads, and porcelains (Bayman et al. 2012).

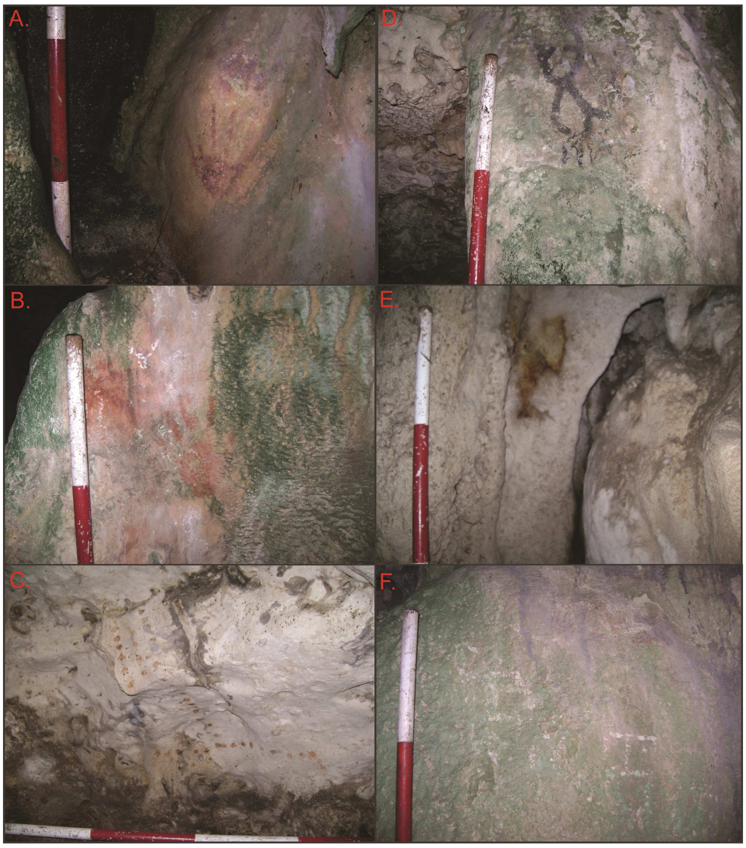

Fig. 11：Examples of rock-art pictographs in Ritidian caves. Scale bars are in20-cm increments

Fig. 12：Photograph of Spanish-era stone-faced terrace at Ritidian. Scale bar is in 20-cm increments.

FAUNAL RECORDS

Certain details of the ancient environmental settings were studied through records of shellfish and other faunal remains in the dated site middens (Figure 13). This effort examined the minimum number of individuals (MNI) in each major category. For the most reasonable comparative analysis, the results were standardized as MNI per 100 liters excavation in each represented time period.

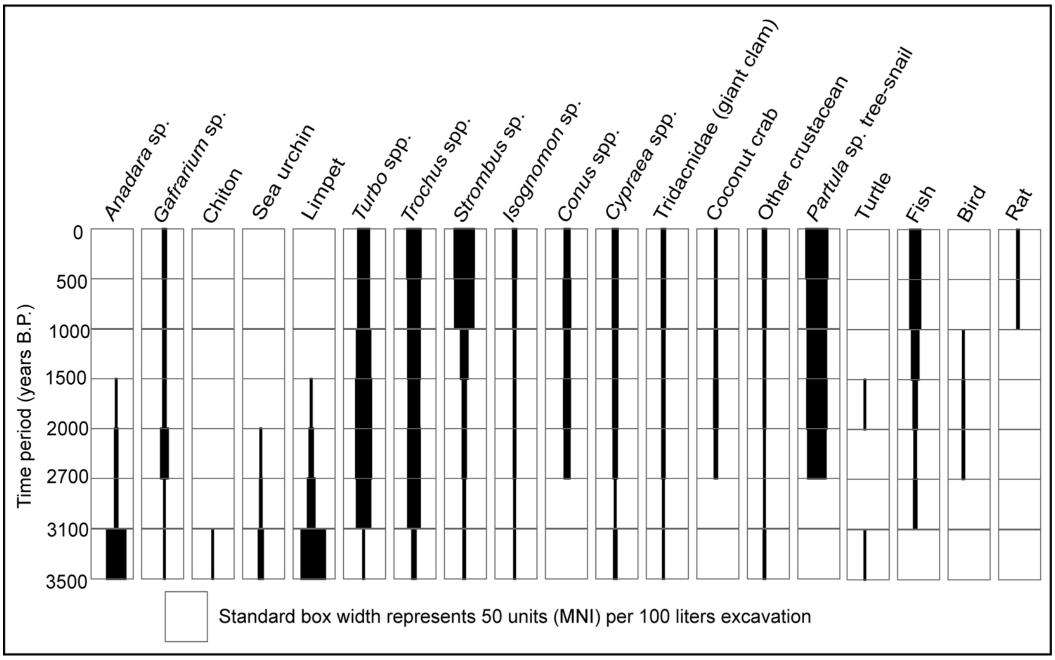

Fig. 13：Summary of Ritidian faunal records. Values are in minimum number of individuals (MNI) per 100 liters of excavation in each represented time interval.

The faunal remains indicate a local nearshore resource depression around 3100–2700 years ago. This pattern appears to be due to the natural sea-level drawdown, combined with impacts of cultural harvesting at the same time. In other sites of Guam where first habitation occurred much later, the cultural harvesting impacts could be separated from the effects of sea-level change (Carson 2012b). Compared to other sites of different ages, the decline in *Anadara* can be linked to the natural sea-level change, but other taxa (e.g., limpets, chitons, and sea urchins) were affected by cultural harvesting shortly after human occupation in each location, regardless of the time period. In the Ritidian case, the co-occurring factors contributed to a localized resource depression, otherwise not witnessed in most other later-dated sites missing the early record of sea-level change.

The decline of *Anadara* and other shellfish immediately was compensated by harvesting other taxa. *Gafrarium* could tolerate the changing coastal conditions better than could *Anadara*. More important in a long-term view, shellfish such as *Turbo* and *Trochus* from the middle-outer reef were more resilient to the changing ecosystem. Just a few of these large shellfish could provide more protein and nutrition than several dozens of *Gafrarium*.

The later part of the Ritidian sequence shows a marked increase in *Strombus* in the site middens. The particular species was the rather small *Strombus gibberulus*, overwhelmingly dominant in most *latte* period site middens (Carson 2012a). The species apparently thrived in the new lagoonal systems of this later period, and moreover the shellfish may have become a preferred culinary ingredient.

Another important finding in the Ritidian faunal record was the appearance of terrestrial snail shells, namely the tree-snail *Partula* sp., following the formation of larger stable terrain. These animals live in forested areas, so their absence in the earliest period likely reflects an absence of forested habitat. Their increasing presence later indicates the expanding coastal terrain with healthy forest growth. *Partula* are considered endangered today in Guam, so their more abundant archaeological occurrence gains more interest for studying long-term forest ecology.

When considering faunal records, the absence of domesticated animals has posed a curious issue in the Marianas (Wickler 2004). The long distance of ocean voyage may have made translocation of animals impractical during the earliest settlement period. In most other Pacific Islands, domesticated pigs, dogs, and chickens were introduced by the earliest Austronesian settlers. The difference in the Marianas case undoubtedly contributed to a separate trajectory of landscape evolution, but it also implies a unique migration route apart from what occurred elsewhere in Oceania with successful animal transport.

3500–3100 YEARS B.P.

The earliest site occupied at Ritidian was a small patch of unstable sand between the high and low tide (see Figure 6-A), where a stilt-raised house likely stood over or near the shallow water. The original cultural layer was buried 235–260 cm (Figure 14), containing thin redware pottery, burned coral cobbles, shellfish remains, and animal bone fragments. The materials were found within a natural deposition of intact *Halimeda* sp. algal bioclasts, overlaying a slightly older *Heliopora* sp. coral formation.

So far, only a 1 by 1 m excavation found this earliest cultural deposit. Other test pits at 10-m intervals did not encounter cultural materials at this depth. The oldest site deposit therefore is confined within less than 20 by 20 m.

The pottery in the lowest layer was broken from thin red-slipped vessels (see Figure 7-A and-B). The collection consisted of 428 pieces (793.5 sq cm) from the single 1 by 1 m excavation. None of these pieces showed significant erosion, and many could be re-fitted. Close examination concluded that the fragments represented about 10–20% of two different small bowls or jars, plus more than 55% of another shallow open bowl.

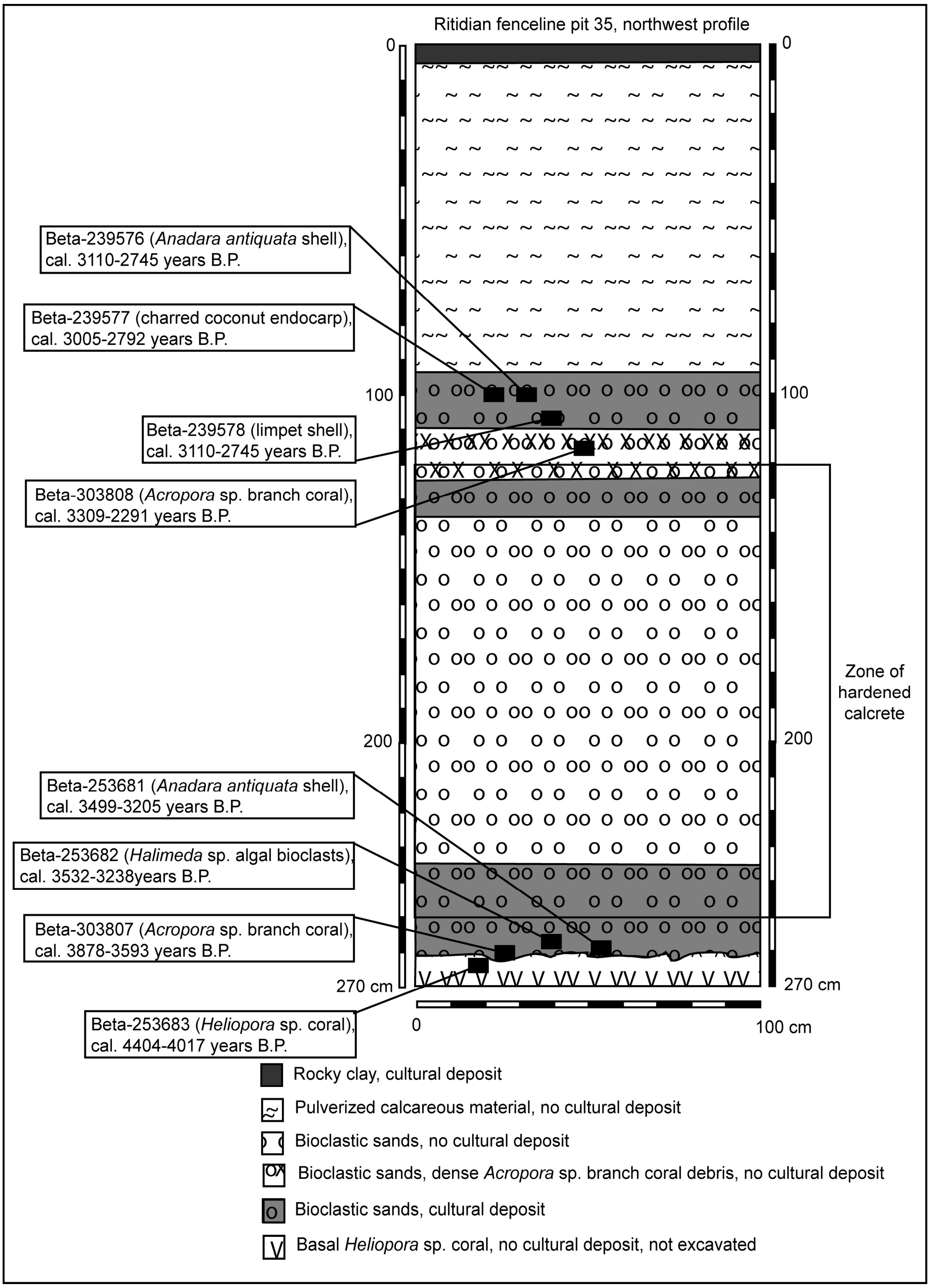

Fig. 14：Stratigraphy and dating at Fenceline Pit 35.

According to discarded shellfish remains, people harvested arc clams such as *Anadara* sp. that soon declined rapidly in numbers with a falling sea level and loss of their preferred habitats in swamp-like shallow waters and grass-beds. Sea urchins and chitons were among the earliest local meals, absent in later contexts probably due to combined stress by harvesting and changing coastline. Various limpets experienced a similar but more prolonged decline.

A date range of cal. 3499–3309 B.P. (years Before Present = before A.D.1950) is proposed for the lowest cultural layer, based on redundant statistical overlap of two dated samples (see Figure 14). First was *Anadara antiquata* shell at cal. 3499–3205 B.P. (Beta-253681). Second was freshly deposited *Halimeda* sp. algal bioclasts at cal. 3532–3309 B.P. (Beta-253682). Despite careful recovery and sieving through one-half-mm mesh, no datable charcoal was recovered, presumably due to the original inter-tidal setting during a time of sea level 1.8 m higher than today.

The early age has been supported by additional samples in lower (pre-dating) and upper (post-dating) positions. Directly pre-dating the cultural layer, a segment of *Acropora* sp. branch coral was dated cal. 3878–3593 B.P. (Beta-303807), from a context at 262–263 cm lodged within a crevice in the underlying *Heliopora* sp. coral dated cal. 4404–4017 B.P. (Beta-253683). In a much later stratigraphic position at 110–120 cm within a surge-layer of branch coral debris, another *Acropora* sp. segment was dated cal. 3309–2991 B.P. (Beta-303820), covered by a cultural layer at 93–110 cm dated cal. 3005–2792 B.P. (Beta-239577).

3100–2700 YEARS B.P.

The original site was covered by a massive sand accumulation, followed by occupation of a newly formed beach ridge 3100–2700 years ago (see Figure 6-B). The beach ridge formed within a context of sea-level drawdown, creating strand-like environment, wherein the *Halimeda* bioclastic sands were partly emerged above the falling sea level in some but not all areas. Ridges of these sands formed parallel with the coastline, and people lived along one of them, leaving concentrations of broken pottery, stone tools, and remains of campfires burned directly in the sands.

The beach ridge habitation included two temporal components of initial and later occupation, interrupted by a layer of *Acropora* sp. branch coral debris. The interrupting layer shows that a typhoon, *tsunami*, or other high-energy surge covered the coast, but the habitation immediately resumed. The relevant radiocarbon dating is depicted in Figure 14.

The initial beach ridge habitation contained mixed thin and thick red-slipped pottery, whereas the later continued habitation contained only the thicker variety (see Figure 7-C and -D). The thicker variant was coarsely made, and the vessels were larger bowls and jars. The use of red-slipping was diminished in comparison to earlier pottery.

A broken piece of a probable fish-trolling lure was found within the initial beach ridge habitation (see Figure 8-C). It was made of cut and polished nacreous shell. The particular shell may have been a large piece of *Isognomon*, offering a workable long flat surface as opposed to the more curving nature of *Turbo* or *Trochus*.

During the beach ridge habitation, discarded shellfish midden contained significantly less *Anadara* and increasing frequency of *Turbo* and *Trochus* gastropods. Limpets, chitons, and sea urchins also showed significant decline in size, species richness, and overall abundance.

2700–2000 YEARS B.P.

After sea level was lowering for a few centuries, 2700–2000 years ago people lived on narrow pockets of slightly elevated beaches in scattered locations along the base of the cliff (see Figure 6-C). Shells of the tree-snail *Partula* sp. verify terrestrial habitat and at least some forest cover. People abandoned the prior choice of shoreline zones that had become barely recognizable. They now instead inhabited newly formed pocket beaches at the cliff-base, specifically in loci directly outside small caves.

The caves themselves bear no evidence of human use during this period, but presumably proximity to the caves somehow was important for the immediately adjacent habitations. Dripping water could be collected inside the caves. Burned remains of large crabs reflect meals of the coconut-robber *Birgus latro* known to dwell in these settings. The caves may have provided temporary shelter from typhoons and adverse weather, but no identifiable cultural deposits developed in the interior spaces until much later.

Outside the caves, the cultural layers contained dense charcoal and ash, unlike the scant or non-existent charcoal in prior occupation periods. Partly, this change was due to better preservation conditions in the stable elevated landforms. However, the density of burned organic material suggests an increased intensity of habitation.

The site settings today are easily recognized as slightly elevated terrain hugging the base of the cliff directly outside caves (Figure 15). More recent artifacts and midden cover the surface, extending downward variable depth. The older deposits are completely buried, detectable only through excavation.

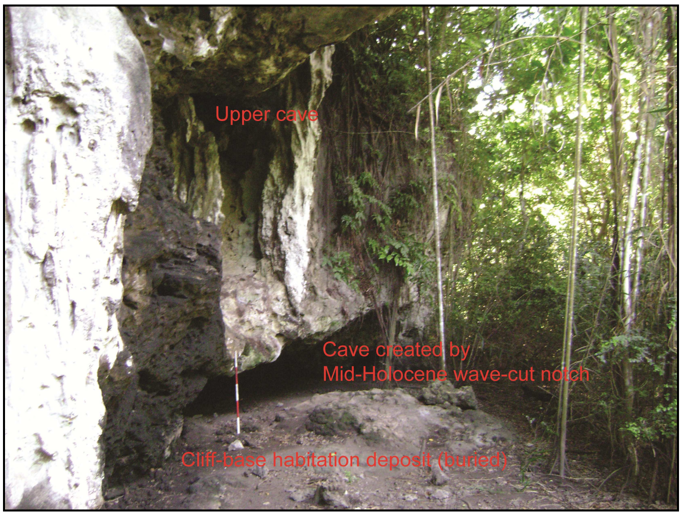

Fig. 15： Example of cliff-base habitation site. Scale bar is in 20-cm increments.

In some cases, the adjacent caves were created during the preceding era of higher sea-level prior to 3000 years ago. These particular caves were formed by wave-cutting of notches into the limestone. The elevations correspond with the 1.8 m higher sea level. The caves and the adjacent pocket beaches therefore could not have been occupied until after the sea level began to lower, generally following 3000 years ago at the earliest.

Five cliff-base habitations were identified of this time-range, based on relative stratigraphy and pottery association. The age was confirmed by radiocarbon dating at two locations (Figures 16 and 17). According to both radiocarbon results and pottery associations, these two cases represent the earliest and latest of the time-range. Toward the end of this period, a few flat-bottomed shallow pans were produced (see Figure 7-E).

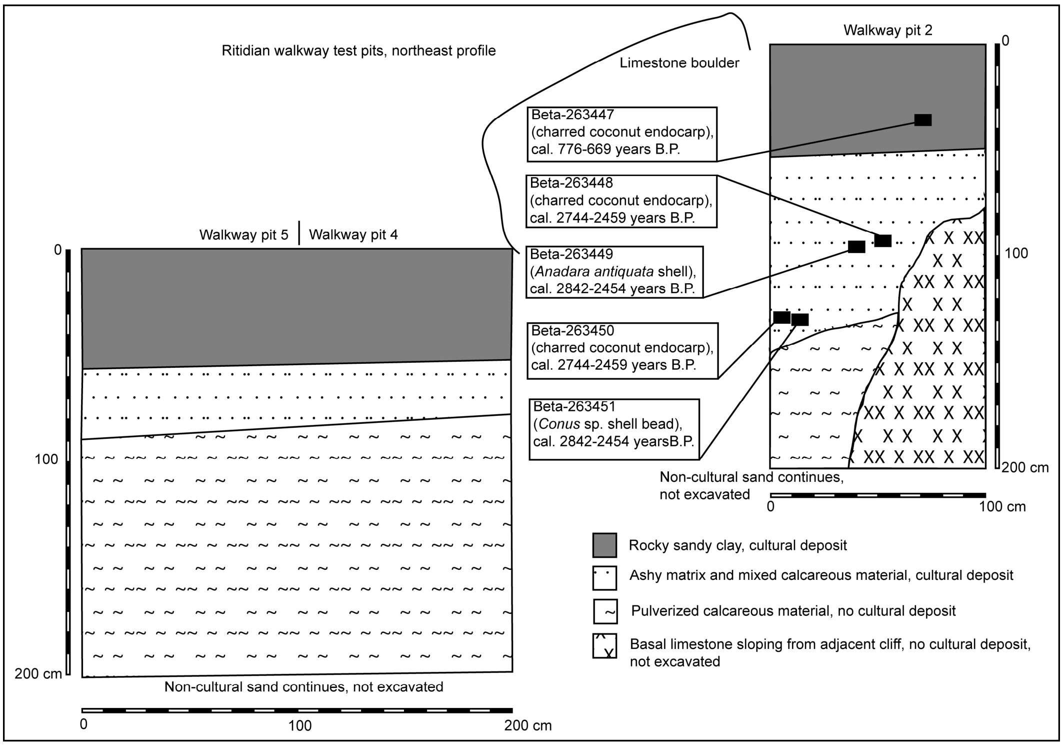

Fig. 16：Stratigraphy and dating at Walkway Pits 2, 4, and 5.

The trends that already had begun in the shellfish records now continued. *Turbo* and *Trochus* shells were most commonly represented. Small amounts of bird bones appeared for the first time, possibly indicating a change in access to different resource zones.

Numerous *Conus* shell beads (N=71) were found at one location, likely broken from a single original necklace strand (see Figure 8-D). Similar beads are known at other Marianas sites, often earlier but generally ending production around 2000 years ago. In later periods, shell beads were larger and less thoroughly polished.

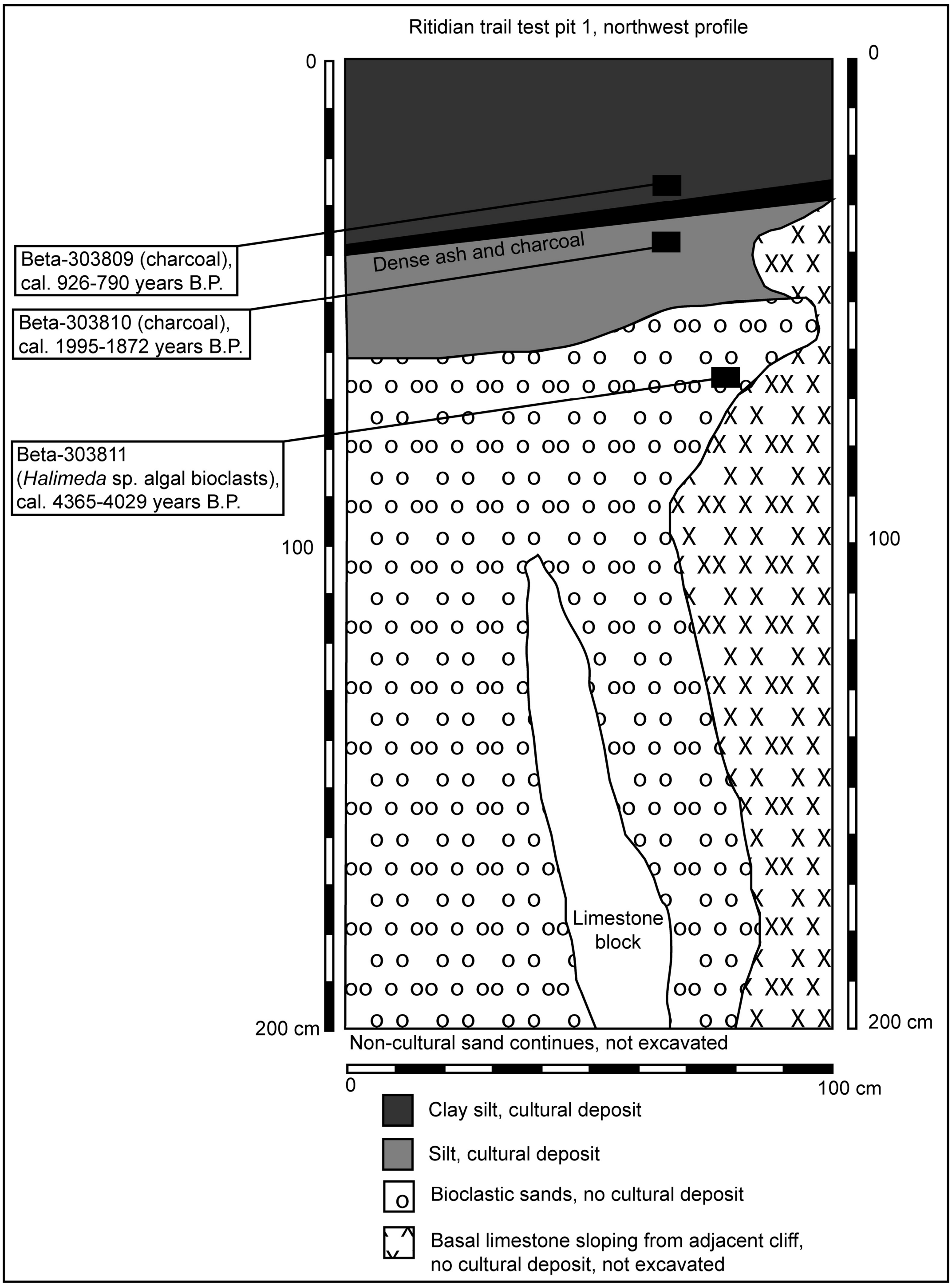

Fig. 17：Stratigraphy and dating at Trail Test Pit 1.

2000–1500 YEARS B.P.

A broader coastal landform developed 2000–1500 years ago, as the former shallow lagoon became mostly filled but not entirely stable above sea level (see Figure 6-D). Habitations remained at the most secure cliff-base spots while expanding modestly in size by just a few sq m at each location. Dense ash, pottery, other artifacts, and food debris indicate intensive residential occupation.

The most clearly diagnostic pottery type at this time was a large flat-bottomed shallow pan (see Figure 7-E). The popularity of this new design signified a change in food production and consumption. Larger serving-sizes now were evident, possibly reflecting growth in household size. The shallow pans may have been griddles, reflecting a different cooking practice than previously evidenced. Pending taxonomic identifications, thick burned starchy residues most likely represent breadfruit, taro, or yam.

In at least one cave, limited cultural activity occurred during this time. Curiously, no artifacts are present during this period or any other. The only surviving cultural evidence includes discarded shellfish remains and sparse ash.

1500–1000 YEARS B.P.

The coastal plain began to approach current conditions 1500–1000 years ago (see Figure 6-E). The former lagoon was stable above sea level, and a new reef ecosystem was growing in its more seaward location known today. The former lagoon was now entirely buried in some cases more than 2 m beneath the young coastal plain. A surface of organic soil horizon began to form, only weakly over the bioclastic sands. Habitations intensified at the same cliff-base sites, while low-intensity activities were diffused over the newly expanded terrain.

1000–500 YEARS B.P.

A revolution occurred 1000–500 years ago in cultural use of the landscape (see Figure 6-F). The total habitation area at Ritidian exceeded 100,000 sq m, as compared to less than 1000 sq m throughout the prior 2500 years. This incredible size-increase was linked to construction of formal *latte*-type megalithic house-posts (Laguana et al. 2012). These sites were built not just at Ritidian but throughout even the smallest and most isolated of the Mariana Islands.

Along with the new *latte* constructions and large-scale land-use, many aspects of material culture changed at this time (Carson 2012a). Large and thick pottery was produced prolifically (see Figure 7-H). Mortar depressions were carved into boulders and sometimes into limestone bedrock for processing plant foods and possibly other purposes (see Figure 10). Ritual use of caves was commemorated in painted pictographs of human figures, hand-prints, and various enigmatic images (see Figure 11).

By 1000–500 years ago, the habitat of the original island colonists no longer existed, but instead conditions resembled more or less the modern structure. Forest growth was luxuriant, as seen in thicker soil development and abundant *Partula* shells. At an island-wide scale, though, the forest transformed in concert with agricultural land-clearing (Athens and Ward 2004) and first introduction of rats (Pregill and Steadman 2009).

In terms of people adjusting to the new coastal ecosystem, the ancient preference for *Anadara* shells was impossible in the altered environment by 1000 years ago, long since replaced by other shellfish taxa. Beginning about 1000 years ago, *Strombus* gastropods dominated the site middens, in part due to the favorable new habitat of open sandy nearshore zones. This rising importance of *Strombus* added one point to the pre-existing trends in the shellfish records, but this additional point was remarkably voluminous.

500–0 YEARS B.P.

The most recent 500-year period encompasses encounters between the native population and Spanish colonial powers. After years of conflict most severe during the late A.D. 1600s, the native population was vastly reduced, and survivors were re-located into a few easily controlled villages in Guam. Following this *reducción* period, the desertion of Ritidian and other indigenous villages led to abandonment of traditional management of the forest, lagoon, and other resources. Meanwhile, exotic animals such as pigs, deer, horses, water buffalo, and others began to degrade the terrestrial ecosystem, later even more devastating when the infamous brown tree snake nearly exterminated native avifauna. Today, fruit bats also live in dangerously low numbers.

In the years preceding the Spanish *reducción* period, *latte* village habitation was most intensive and widespread. Nearly all of the surface-visible ruins date to this particular era (see Figure 6-G), also incorporating a few new additions of stonework due to Spanish influence. These findings indicate that Spanish colonial contact occurred during a time of growing indigenous population, possibly already nearing a critical state.

Along with escalating density and extent of *latte* villages, cave interiors show increased cultural use, reflected in greater density of shellfish remains, ash, and charcoal. Given the continued absence of artifacts, cultural use of caves probably was restricted in scope. Rock-art images suggest ritual contexts, perhaps further reinforced by scattered human skeletal remains in at least two cases.

CONCLUSIONS

The Ritidian case study illustrates a shift from a narrowly specialized shoreline niche exploitation to broader-scope land-sea ecosystem management, through extended processes linking the changing environment, cultural use of the landscape, and population growth. Three major points can summarize the sequence:

(1) The first Austronesian colonists targeted specialized shallow-water reef zones 3500 years ago, but this lifestyle became unsustainable by 2700 years ago, when the coasts and reefs had transformed past a threshold no longer supporting the original niches.

(2) Newly formed small patches of landward terrain then became the preferred habitation locales, soon thereafter expanding as the stable coastal landforms continued to prograde.

(3) The most extensive coastal terrain was stabilized by 1000 years ago, coinciding with regional population growth and expansion, greatly intensifying the cultural impact on the landscape.

This study shows that the habitat structure or landscape ecology at any one time did not occur in isolation, but rather it was shaped by a longer chronological sequence. The oldest and youngest time periods were almost entirely foreign to one another, in terms of the physical setting and how people behaved within the given setting. In other words, the ecological relationships became substantially different over time, so that acceptable cultural practice in one era was not necessarily suitable or even possible in another era.

At some time following the initial Austronesian settlement, a significant change occurred in the landscape structural identity. The environment and associated cultural practice of this early period simply did not exist in later centuries. People attempted to maintain the original lifestyle through changing conditions, for example shifting habitation from the shoreline to newly formed beach ridges and then to other coastal landforms. They meanwhile adjusted shellfish-collection strategies and presumably other resource-use as well. At a certain point, though, all of these factors changed to such a degree as to compose an entirely different ecological structure, especially concerning the role of human communities within the landscape.

In addition to the early-period landscape change, another major change occurred after 1000 years B.P., during the period of megalithic *latte* sites (Carson 2012a). The large residential village at Ritidian was only one of several throughout Guam and the other islands of the Marianas, all created during this later period within the last 1000 years. Populations expanded into new territories, and the small islands north of Saipan were settled for the first time.

A suddenly larger resident population size certainly must be acknowledged about 1000 years B.P., but a *possible population replacement* has not yet been resolved. Not enough is yet known to discern the possible scenarios of: a) local population increase, creating substantively new developments overtaking pre-existing traditions; b) invading groups replacing the local population; or c) combination of both scenarios. These issues will need further examination at sites with detailed records throughout the few centuries directly before and after 1000 years B.P.

Concerning the habitat of initial Austronesian settlement 3500 years ago, the colonists evidently favored locales at the shoreline with direct access to productive coral reefs, mangroves, and nearby forested land-mass. These habitations were widely dispersed from one another, each occupying an ideal nexus of primary natural resources. The uninhabited territory and even some entire islands served as potential supplementary resource zones. The ability to recruit from a potentially broad resource catchment may have been critical for survival of the founding colonies.

Comparing the earliest Marianas settlement with pre-existing Austronesian modes of landscape relations in Taiwan and the northern Philippines, the Marianas case expectedly exhibits unique differences in this truly isolated and small-island setting. A coastal-maritime economy seems logical for an obviously sea-oriented people making the unprecedented long-distance voyage to these remote islands. At the same time, though, land-based food-production equally was essential for nutritional survival, but it required special strategies in the remote islands where most economically useful plants needed to be imported. Coconuts (*Cocos nucifera*) and a local seeded breadfruit (*Artocarpus marianensis*) provided some baseline plant-food subsistence, but other tree and root crops necessarily were transported.

Along with the imported plants, people brought notions of how to create and maintain cultivated landscapes, presumably reflecting an inherited Austronesian landscape system, but an exact replication was not always possible. For example, the systems as known previously in larger land masses like Taiwan and the northern Philippines were not practical in the Marianas. Rice and millet were important crops in Taiwan for more than 1500 years prior to Marianas colonization (Hsieh et al. 2011), but the physical landforms in the Marianas did not include suitable plots for rice-farming, at least not during the earliest settlement period as described here. Moreover, a presumably small colonizing population may not have been able to manage large-scale investments in agricultural systems. Rice reportedly was grown during Spanish colonial contexts in the A.D. 1600s and probably earlier, but it was in small amounts and lacking formalized fields. Instead, mixed tree and root crops were dominant, but these were grown in informal managed forests and family gardens, not in formalized field systems (Dixon et al. 2012).

The creation of a new Austronesian landscape in the Marianas further differed from prior examples by excluding domesticated animals from the land-use system. The full package of land-use and subsistence therefore was missing a number of key components. These components related to each other in ways that are not always obvious in material archaeological evidence, much like the inter-actions of ingredients in a cooking recipe.

With certain ingredients missing in the Marianas case and others added for the first time, an original inherited Austronesian formula for landscape management could not be replicated exactly. Rather, some other product was necessary with the available materials, ingenuity, and skills. The result was a new system of Austronesian landscape suitable for a remote and small-island setting, previously not experienced. This somewhat experimental new system worked in the Marianas, and variations of this theme were applied in other remote Pacific Islands. One important difference is that pigs, dogs, chickens, and rats accompanied other Pacific Island colonists, although they did not appear in the Marianas until thousands of years later (Wickler 2004). Different modes of irrigation works, dryland mounds, field borders, and other durable land-shaping complexes developed throughout the Pacific Islands for tree and root crops (Carson 2006), but the Mariana Islands were among the places where no such elaborate systems developed. The remoteness and the slightly earlier colonization of the Marianas, compared to other Pacific Islands, could explain the absence of some of the hallmarks of other Remote Oceanic colonizing systems.

An emphasis on coastal-maritime resources further accentuated the uniqueness of this new system in the Marianas, but it was not permanent. This originally successful strategy eventually needed to change, following substantial coastal geomorphological transformations. Other adaptations became necessary after cumulative cultural impacts on the ecosystem, increased population growth, and various internal social developments.

A single model of Austronesian landscape was not always practical throughout the diverse geographies, natural histories, and cultural settings of the Austronesian world. At least a few major landscape adaptations accompanied Austronesian expansion into new parts of the great Asia-Pacific. Other aspects of landscape evolution occurred throughout long-term habitation at individual places. All of these points are illustrated in the Ritidian research. Future efforts can expand for cross-regional comparison, not yet undertaken to the extent of the Ritidian case study.

The Ritidian example emphasizes that the landscape ecology seen today embodies complex long-term outcomes of intimate human-environment relations. As outlined here, the sequence of landscape ecology and evolution represents an integrated natural-cultural history and heritage. Modes of landscape relations at any one time are partly inherited from prior events and processes, not always by choice, but they nonetheless set the parameters within which social-ecological systems continue to evolve.

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南島語族地景的演化：關島 Ritidian 遺址

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地質考古學的研究已經揭露了馬里亞納群島（Mariana Islands）中位於關島（Guam）的瑞提迪恩（Ritidian）遺址的地景生態與演化。本文則進一步描繪出南島語族族群第一次居住於一個偏遠小島的情形。在此，一項整合自然史與文化史的地景研究完整地呈現了這個獨特而孤立的最早期聚落及其後數百年的演化情形。

關鍵字：太平洋地質考古學、地景、生態學、關島、馬里亞納群島