Micronesica Suppl. 2: 47–64, 1990

Lime–Encrusted Shell Artifacts and the Prehistoric Use of Slaked Lime

James Carucci

Center for Archaeological Investigations, Southern Illinois University Carbondale, IL 62901

and

Steven Mitchell

Department of Geology, California State College, Bakersfield 9001 Stockdale Highway, Bakersfield, CA 93311

Abstract—During recent excavations on Rota in the Mariana Islands, a number of shell artifacts which contained multiple layers of a carbonate compound were recovered. These artifacts are related to the manufacture and use of burned lime, and fall into two categories: lime scoops or containers, and bivalve scrapers. Samples of the carbonate material from several of the artifacts were tested with an X-ray powder diffractometer and compared to the deposits which remained in several non-artifact shells. Natural carbonate encrustations can be differentiated from deposits of culturally produced lime, allowing lime–encrusted shells to be sorted into artifact and nonartifact categories. A typology of the artifacts related to the use of slaked lime is presented, and the function of the different artifact types is discussed.

Introduction

In 1984, the Center for Archaeological Investigations (at Southern Illinois University, Carbondale) conducted a series of test excavations along the north-central coast of Rota in the Mariana Islands (Fig. 1; see Butler 1988 for complete discussion of the project). During laboratory analysis of the marine foodshell assemblage, a number of unique shell artifacts were identified. These artifacts, represented by three species of gastropod and several bivalve species, contain multiple layers of a white, powdery lime material. Although similar lime–encrusted artifacts are known, previously published descriptions have been very general and tend to focus only on those artifacts which are fashioned out of gastropod shells. Little has been said of the bivalves, which appear to have utilized scraper edges as well as deposits of lime identical to the material found in the gastropods. In this paper, we describe both kinds of artifacts, report the results of observations and laboratory tests performed on samples of the lime paste, and suggest a behavioral use pattern which accounts for the lime–encrusted bivalves.

Statement of the Problem

The lime–encrusted shell artifacts recovered from the controlled test excavations on Rota are identical to artifacts which have been found on Guam (Reinman 1977: 116, Fig. 40; Ray 1981: 235–236) and Saipan (Spoehr 1957: 156–157). While these artifacts have been described as "lime containers" or "lime holders," very little analysis has been con-

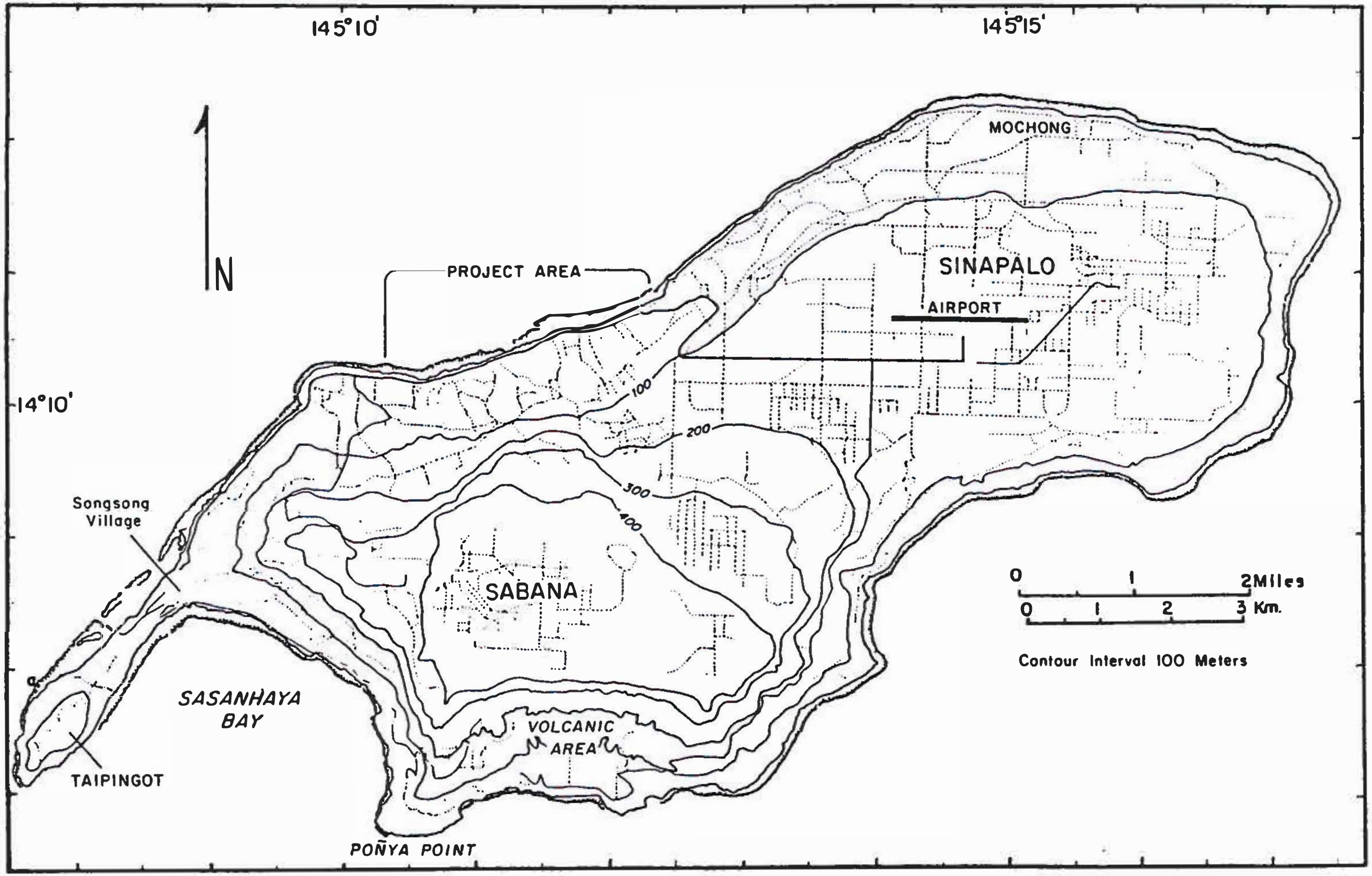

Figure 1. Map of Rota showing the project area.

ducted on them. Most archaeologists suggest that the encrusted gastropods served as lime scoops or containers, the bivalves were probably lime containers, and all the encrusted shell artifacts were related in some way to the consumption of betel nut. Using several different methods, this paper will address three questions concerning the lime–encrusted shell artifacts. First, what is the chemical nature of the powdery deposits, and is it demonstrably cultural in origin? Second, are the layered powdery deposits which remain in the gastropods the same as those which remain in the bivalves? Finally, if the deposits in the gastropods are the same as those remaining in the bivalves, what functional differences (if any) might there have been between the two types of artifacts?

Descriptions of the Lime–Encrusted Artifacts

During the sorting and analysis of the foodshell assemblage from Rota, a number of different shells containing a crusty white deposit were noted (for a complete discussion of methodology used, see Carucci 1988). These shells were thought to be encrusted with natural carbonate deposits until several lime–filled and modified gastropods were discovered. All shells known to contain similar deposits were then reexamined, and two categories of lime–encrusted shell artifacts were defined. One category consists of gastropods which have been modified to serve as lime scoops or containers. The other category of lime–encrusted artifacts consists of bivalves which have been modified through utilization and show evidence of wear along their ventral margins.

Four specimens of the modified and lime–filled gastropods (category one artifacts) were found in the shell collection, one of which is illustrated in Figure 2. It is a *Purpura persica* (Dance 1976: 135) which measures 4.04 cm long, 2.79 cm wide, and 1.77 cm thick. The internal columella has been removed and the shell hollowed out. Much of the shell interior is still caked with lime. On the outside of the shell, at the base near the anterior canal, a spot has been filed flat and a hole has been drilled through the shell. Although no evidence of cordage was found, the hole would have allowed the scoop to hang from a neck lanyard or other cord. A burnished area is apparent two-thirds of the way

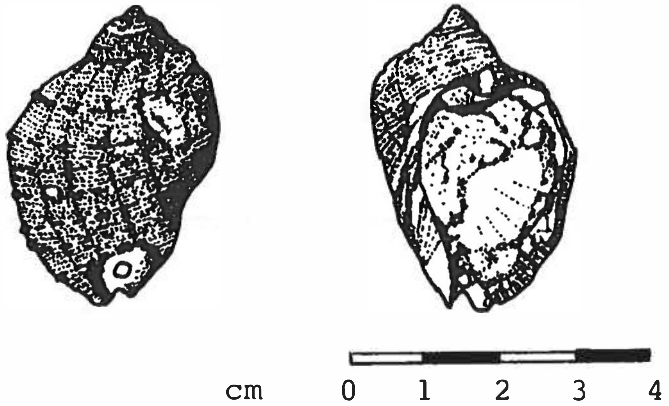

Figure 2. Category 1 lime filled gastropod artifact. This is a *Purpura persica* lime filled scoop. Note burnished area on upper exterior and the anterior section which has been filed flat and drilled.

up the exterior periphery of the shell. This presumably resulted from the artifact being used as a lime scoop. When it was repeatedly dipped into a larger container of lime, the exterior of the shell would have rubbed against the surface of the container.

Two artifacts identical to that shown in Figure 2 have been reported from other islands in the Marianas. Spoehr (1957: 156) describes an "ancient shell lime container" which was found on the surface at the Objan Site on Saipan. Spoehr (1957: 156) noted that "a deposit of lime remains in the shell, and the deposit itself contains a well-delineated finger impression. The shell container is perforated, probably to accommodate a cord hung around the neck of the user." Although Spoehr did not identify the shell species, from the photograph it appears to be a *Purpura persica*.

The second artifact was recovered from a depth of 12 to 18 inches (30 to 45 cm) at the Nomna Bay site on Guam (Reinman 1977: 116, 192, Fig. 40). Again, based on the photograph, the shell appears to be a *Purpura persica*. In addition to being the same species of shell, each lime scoop was apparently drilled for a suspension cord and each contained deposits of a white powder.

Two other modified gastropods from the Rota assemblage are fragments of large cowrie shells. Although physically possible, it is unlikely that these fragments originated from the same artifact. The fragments were recovered from different test pits and different depths. Both fragments have been identified as *Cypraea tigris*, the Tiger Cowrie. The larger of the two comprises nearly one half of the entire shell and measures 6.38 cm in length (Fig. 3). A recent fracture has removed the dorsum of the shell. The narrow aperture at the base has been expanded into a large round opening, forming the entire shell into

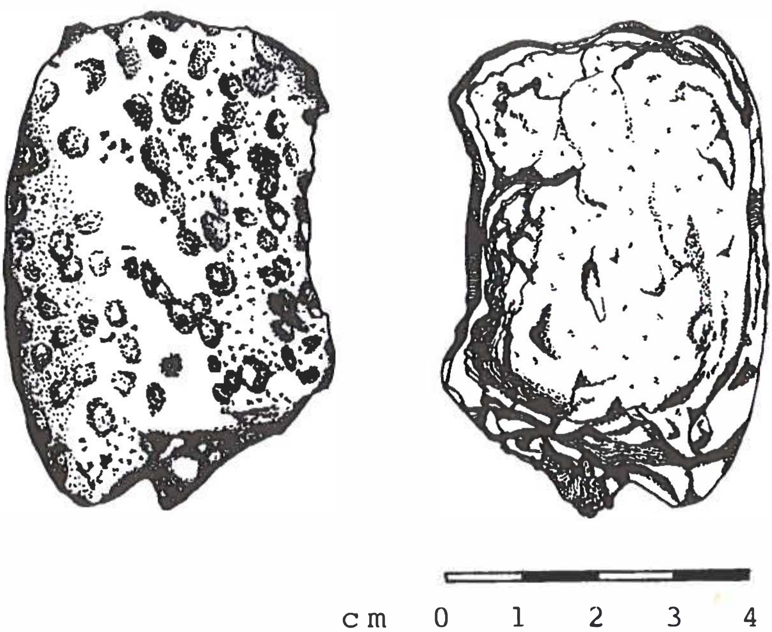

Figure 3. Category I lime filled shell container. This is a large fragment of a *Cypraea tigris* shell. Note extensively layered lime deposits in the interior.

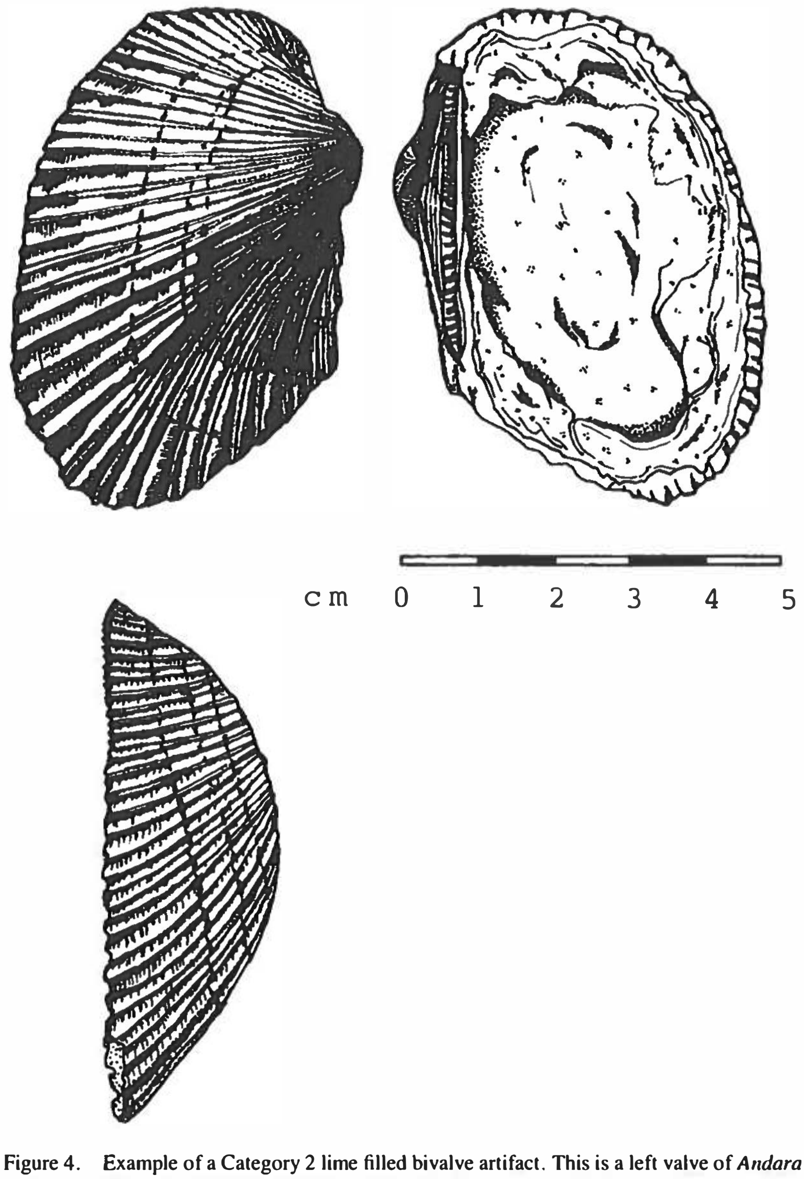

Figure 4. Example of a Category 2 lime filled bivalve artifact. This is a left valve of *Andara nodifera*. The external surface has been smoothed by use and the ventral edge exhibits wear. The interior is filled with a thick layer of lime.

a cup-like container. Most of the interior is extensively layered with carbonate deposits up to 6 mm thick, suggesting it was used repeatedly to store lime.

The last lime–encrusted gastropod found in the collection is a large *Turbo* sp. fragment. It has a smoothed exterior and contains a small amount of layered lime deposits. It may have served either as a scoop, or a scraper tool of some sort.

The second category of lime–filled shells consists of utilized bivalves (Fig. 4). A

Table 1. Summary of lime-encrusted shell artifacts by family, genus and species.

Shell Family	Valve Side Left/Right	Genus/species	Number of Lime Encrusted artifacts
Arcidae	1 / 5	*Anadara nodifera*	6
Lucinidae	– / 1	*Codakia* sp.	1
Psammobiidae	1 / 2	*Asaphis violascens*	3
Tellinidae	2 / 3	*Tellina rugosa*	5
	1 / 3	*Tellina scobinata*	4
Veneridae	1 / –	*Periglypta reticulata*	1
Total:		Lime Encrusted Bivalves	20
Gastropods			
Cypraeidae		*Cypraea tigris*	2
Muricidae		*Purpura persica*	1
Turbinidae		*Turbo* sp.	1
Total:		Lime Encrusted Gastropods	4
Total:		All Lime Encrusted Artifacts	24

total of 20 utilized bivalves was identified in the collection, representing six shell species. All of these artifacts exhibit moderate to heavy edge damage along their ventral margins. The sharp ventral margins of the shells appear to have been used as scraping edges, and the naturally rough exterior surfaces of the valves are abraded and worn as if by repeated rubbing or scraping. Each valve contains a variable amount of lime on its interior surface and this lime appears to be identical to the deposits found in the gastropod artifacts. However, the material remaining in the bivalves is not as extensively layered as that in the gastropods. Of the six bivalve species in this category, three account for two-thirds of the total number of artifacts. These are: *Anadara nodifera* (n=6), *Tellina rugosa* (n=5), and *Tellina scobinata* (n=4). These same species of shell are known as scrapers and smoothing tools in Palau and Truk (Masse unpub., King & Parker 1984). A summary of the lime–encrusted artifacts from Rota appears in Table 1. The bivalves are reported by total species counts as well as left and right valve counts.

Natural Carbonate Encrustations and Culturally Produced Lime

In Micronesia, the production of slaked lime requires the use of great quantities of wood for fuel (S. Russell, pers. comm; K. Blaiyok, pers. comm.). When the wood is burned, soot, ashes and other carbon compounds are produced which contaminate the lime. In most cases, simple visual inspection allows shells containing culturally produced lime to be differentiated from shells having natural carbonate concretions. Carbonate deposits which have resulted from various natural chemical processes will not contain carbonized wood particles or other by-products of the burning process.

However, under certain conditions, shells filled with natural carbonates may be mistaken for lime–filled artifacts. Archaeological materials recovered from deep contexts at beach sites in Micronesia often have naturally produced carbonates adhering to them

(Gifford & Gifford, 1959). This phenomenon is especially prevalent when excavations occur near the Ghyben-Herzberg fresh water lens (Thomas 1965) or when deep excavations approach the terminal layer of beachrock. The precipitation of carbonates onto shells, pot sherds, or other artifacts, or the cementation and lithification of unconsolidated beach detritus into solid beachrock can occur with amazing rapidity, and is thought to be related to the intertidal fluctuations of sea water or the percolation of fresh water (Milliman 1974). While the crystalline structure and matrix of a given deposit of beachrock will vary according to local environmental conditions, the cement mineralogy is uniform. Either magnesian calcite or aragonite serve as the cement which binds the sand, shells, and other beach detritus into a solid matrix. In addition, some researchers have suggested that carbonate precipitation is triggered by organic deposits in beach sand (Milliman 1974), a situation normally present in cultural middens. It is probable, therefore, that shells which have natural carbonate deposits will be encountered in most excavations undertaken in the tropical Pacific.

A number of lime-encrusted shells from the Rota collection were examined under a low-power microscope. Several lime-filled bivalve scrapers, the two *Cypraea* fragments, and a few non-artifactual shells were also examined for comparison. The latter were unmodified shells which were selected because they appeared to have natural carbonate concretions adhering to them. Under low-power magnification, the natural concretions appeared granular. Fragments of coral, foraminifera, and sand particles of varying sizes could be discerned. Conversely, the lime deposits in the *Cypraea* artifacts and modified bivalves exhibited a uniform grain size and did not contain any appreciable amounts of sand, coral or foraminifera. Visually, the deposits in the *Cypraea* fragments and bivalve scrapers appeared identical, although the lime material encrusting the bivalves was somewhat less lamellar. Each sample of the carbonate material removed from the artifacts contained minute black particles, which under high magnification appeared to be pieces of carbonized wood. No such inclusions were noted in the deposits from the non-artifactual shells. These observations suggest that the carbonates found in the modified lime-filled artifacts are the remains of slaked lime which was very likely produced by burning.

When lime-filled artifacts are encountered in a shell assemblage, the analyst must be sure that the carbonate deposits are not natural in origin. Caution is especially important if the shell materials derive from a deep excavation in a calcareous beach environment. If a shell suspected of being a lime-filled artifact exhibits large, grainy deposits of cemented sand, coral, and other unconsolidated carbonate materials, the deposits are most likely natural. Furthermore, if the grainy deposits vary greatly in size, particles of carbon are not noted, and the shell is unmodified, it is even more likely that it is a naturally encrusted shell and not an artifact.

A second method for determining whether carbonate deposits are cultural or natural is through an examination of provenience. Natural carbonates are more likely to occur at depths near the fresh water horizon, or near layers of lithified beach materials. Table 2 summarizes the context of recovery for all lime-filled artifacts in the Rota assemblage. All the artifacts were recovered from between 30 to 140 cm below surface and most tend to cluster around 30 to 80 cm. This range is well above the fresh water lens, and well above the barrier of solid beachrock which was encountered at 3 or 4 meters below surface in most of the excavated areas. With the exception of two bivalves recovered from the deepest contexts, the carbonate deposits in the shells are more likely to be cultural than

Table 2. Provenience information for all lime filled artifacts from Rota. Associated radiocarbon dates are also noted*.

Test Pit	Depth cm bs	Artifact Description	Comments
1	70–90	*Codakia* sp. scraper	Right valve
16	30–40	*Cypraea tigris* container fragment	SAMPLE #1
	40–50	*Anadara nodifera* scraper	Left valve; FIGURE 4
	60–70	*Asaphis violascens* scraper	Right valve
	60–70	*Periglypta reticulata* scraper	Left valve
	60–70	*Tellina scobinata* scraper	Left valve
	60–70	*Tellina scobinata* scraper	Right valve
17	20–30	[^{14}C Sample Beta-12433]	AD 1007
	70–80	*Purpura persica* lime scoop	FIGURE 2
	70–80	*Anadara nodifera* scraper	Right valve
18	40–50	*Cypraea tigris* container fragment	SAMPLE #2; FIGURE 3
	50–60	*Anadara nodifera* scraper	Right valve
	90–100	*Asaphis violascens* scraper	Right valve; cultural and natural concretions
	100–120	*Tellina rugosa* scraper	Right valve
19	20–30	[^{14}C Sample Beta-12432]	AD 663
	30–40	*Asaphis violascens* scraper	Left valve
	40–50	*Tellina rugosa* scraper	Left valve; cultural and natural concretions
	50–60	*Tellina rugosa* scraper	Right valve; cultural and natural concretions
	70–80	*Anadara nodifera* scraper	Right valve; cultural and natural concretions
	90–100	*Anadara nodifera* scraper	Right valve; cultural and natural concretions
20	80–100	*Tellina scobinata* scraper	Right valve; beach worn; cultural & natural concretions
22	40–50	*Turbo* sp. lime scoop (?)	Large, utilized fragment
	50–60	*Tellina rugosa* scraper	Right valve
	120–140	*Tellina scobinata* (unmodified)	Right valve; very little lime
23	35–45	[^{14}C Sample Beta-11863]	AD 1817 [average of 5 dates]
	50–60	*Tellina rugosa* scraper	Left valve
	120–125	[^{14}C Sample Beta-11866]	92 BC
	120–140	*Anadara nodifera* (unmodified)	Right valve; very little lime

* The radiocarbon dates are tree-ring corrected means (Butler 1988: 37).

natural. The provenience data clearly support this conclusion, just as caution is warranted with the two shells recovered from 120 to 140 cm below surface. Although both of these valves apparently contain small amounts of lime, both shells do not exhibit utilized or modified ventral margins. Of all the shells considered to be "lime–filled artifacts," only these two, the deepest, do not exhibit the expected characteristics.

The Chemical Nature of the Lime Deposits

Lime is produced when coral or shell is thoroughly burned and then slaked (rehydrated). When materials such as limestone, coral or molluscan shells are burned, the calcium carbonate begins to break down at temperatures between 650 and 898 degrees Centigrade (Shepard 1956). The burning process drives off carbon dioxide and leaves calcium oxide, a hydrophilic compound. Calcium oxide readily absorbs moisture, forming calcium hydroxide $Ca(OH)_2$. The final product is known as slaked lime and can be distinguished chemically from the original materials and from other naturally occurring carbonate compounds.

While the microscopic examination of the artifacts strongly suggested their deposits were produced by burning, a more discriminating analytical method was needed to determine if slaked lime could be differentiated from natural concretions. Samples of the carbonate deposits were removed from the two *Cypraea tigris* fragments, one of the bivalve scraper artifacts, and two naturally encrusted non-artifactual shells and subjected to analysis using an X-ray powder diffractometer. Five coral fragments were also analyzed.

The X-ray diffractometer can be used to determine the chemical identity of various minerals and compounds. A small sample of the unknown material is removed and ground into a fine powder. The powder is then formed into a thin rod and mounted on the axis of a cylindrical X-ray camera (Tite 1972). Then, a monochromatic beam of X-rays is directed at the sample rod, causing a pattern of lines to be exposed on film. This pattern produces what is called a set of "key lines" which are unique. The spacing, angle, and intensity of the lines depend on the crystal lattice structure of the sample and can be used to determine its identity. In Figure 5, the idealized patterns of three carbonate compounds of interest are reproduced. Note that the key line patterns are very similar but that the three compounds can be distinguished from one another.

The uppermost graph represents calcite, which is also referred to as low magnesian calcite (calcite is a calcium carbonate compound). The formula for calcite is $CaCO_3$, and its structure is described as trigonal. The major key line for calcite occurs at an angle of 29.4. The second graph represents magnesian calcite, which is also referred to as dolomite. Its chemical formula is $(Ca,Mg)CO_3$, and the key line occurs at an angle of 29.8. The third graph at the bottom of Figure 5 represents the compound aragonite. It is chemically identical to calcite, but its crystalline structure is orthorhombic and its key line occurs at an angle of 26.2 (Chen 1977).

Our expectations concerning the X-ray diffractometer analysis were the following. First, we anticipated that the deposits from the lime–filled gastropod artifacts would be identical chemically to the carbonate sample from the lime–filled bivalve scraper. Second, we expected the carbonate samples from both categories of artifacts to differ from the carbonate samples removed from any shells known to be naturally concreted. Third, we expected the carbonate compounds from the naturally concreted shells to reflect the normal chemical processes which govern the precipitation of such compounds in a tropical beach environment. Based on the mineralogy of the various samples, these analytical expectations can be more explicitly stated as follows. First, if the lime material in the shell artifacts is culturally produced by burning, then it should test as low magnesian calcite. Heating will transform both magnesian calcite and aragonite into low magnesian calcite (Milliman 1974). Second, any lime material originating from unburned pelecypod (bivalve) or gastropod shells would test as the compound aragonite. Although several bivalve species and a few gastropods have mixed mineralogies which include magnesian calcite, the majority of tropical marine shell species have a simple aragonitic mineralogy. Third, the minerals which act as cements when buried shells or other carbonate materials

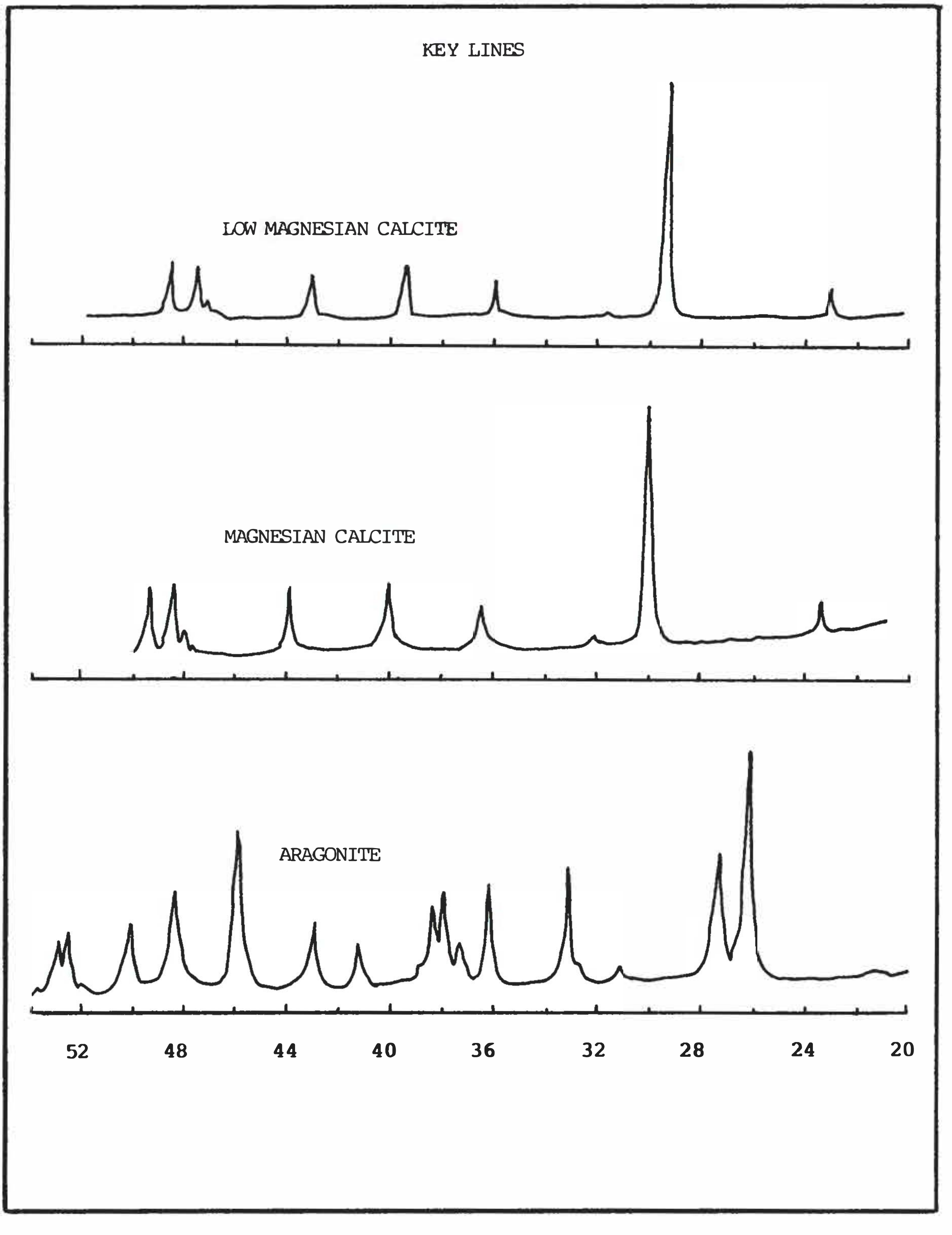

Figure 5. Idealized Key Line patterns of three carbonate compounds.

Table 3. Results of the X-ray powder diffractometer laboratory tests on the carbonate and coral samples.

Sample Number	Sample Type	Test Results	Comments
1	*Cypraea tigris* container	low Mg Calcite	Fine, white crystalline grains from the lime paste in artifacts numbers 1, 2, and 3 were tested. Microscopic examination of samples 1, 2 and 3 revealed minute carbon particles.
1	*Cypraea tigris* container	low Mg Calcite	
3	*Asaphis violascens* scraper	low Mg Calcite	
4	Encrusted *Turbo* sp. [Test Pit 10 60–80 cm bs]	aragonite, Mg Calcite, trace low Mg Calcite	Carbonate sand having molluscs, coral fragments, calcareous alga and foraminifera from inside shell was tested.
5	Encrusted *Cypraea* sp. [Test Pit 16 30–40 cm bs]	low Mg Calcite	Fine white grains from aperture were tested. Carbonate sand, mollusk fragments, crab remains and fish bone also present. The provenience of sample 5 is the same as Sample 1. No carbon particles were noted in samples 4 and 5.
A	Coral—*Favia* sp. (?) [Test Pit 19 20–30 cm bs]	aragonite	
B	Coral—"fan" type [Test Pit 18 80–90 cm bs]	aragonite	
C1	Coral—branch type [Test Pit 16 30–40 cm bs]	aragonite	
C2	Coral—branch type [Test Pit 16 30–40 cm bs]	aragonite	
C3	Coral—"fan" type [Test Pit 16 30–40 cm bs]	aragonite	

are agglomerated, lithified, or simply naturally encrusted, are magnesian calcite or aragonite. Therefore, natural concretions formed from the *in situ* chemical precipitation of carbonates will test as either magnesian calcite or aragonite (Milliman 1974). Finally, all corals collectively known as "branched coral" (Randall & Myers 1983) are of the genus *Acropora* and are aragonitic (Milliman 1974). Consequently, unburned coral and unburned shell will test as aragonite, natural carbonate concretions will test as either magnesian calcite or aragonite, but lime produced from burning coral or shell will test as low magnesian calcite. Table 3 lists the materials tested and summarizes the results.

Results of the Laboratory Testing of the Lime Paste Samples

Small amounts of the carbonate material from three of the lime-filled shell artifacts were tested. Samples 1 and 2 were removed from the heavily layered fragments of the *Cypraea tigris* lime container. A lime-encrusted valve of *Asaphis violascens* yielded sample 3. The powdery white carbonate material which comprised these three samples tested as low magnesian calcite. This is consistent with our expectations. Sample 4 was removed from inside a heavily concreted *Turbo* sp. shell recovered at 60 to 80 cm below the surface of test pit 10. This particular specimen was selected because the shell appeared to be naturally concreted and exhibited no physical evidence of modification. Upon analysis, the carbonate material from inside the shell revealed the presence of aragonite, magnesian calcite and a trace of low magnesian calcite. Sample 5 was removed from the interior of an encrusted and sand-filled *Cypraea* shell. It was recovered from 30 to 40 cm below the surface of test pit 16, the same provenience as the smaller of the two lime-filled *Cypraea* artifacts. The fine white grains from inside the shell tested as low magnesian calcite. Particles of carbonate sand, mollusk fragments, crab and fishbone were also noted in the sample. Finally, analysis confirmed that the five pieces of unburned coral were aragonite, as expected.

The test data indicate our expectations were supported for the most part. Samples 1, 2, and 3 were taken from representative specimens of both types of lime-encrusted artifacts. The only mineral present in these three samples was low magnesian calcite. The deposits in the bivalve and gastropod artifacts are chemically similar. Furthermore, when one recalls that carbon particles are present in the matrix and that magnesian calcite (dolomite) and aragonite are transformed into low magnesian calcite by heat, it is reasonable to suggest a cultural origin for the lime.

The presence of both aragonite and magnesian calcite in sample 4 clearly indicates that carbonates found in unmodified, naturally concreted shells are not the same as the material remaining in the lime-filled artifacts. This was expected and it is consistent with the natural process of carbonate precipitation; the minerals which function as cement in a naturally concreted matrix are aragonite and magnesian calcite (Milliman 1974). The test results for sample 5 are problematic. Sample 5 came from a complete, unmodified *Cypraea* shell specimen. The contents of the shell included a fine white granular powder, sand, and molluscan remains. Based both on microscopic examination and results of the X-ray diffractometer test, the material which comprised sample 5 was clearly not cultural in origin. Although the fine white grains tested as low magnesian calcite, as did samples 1 through 3, the material did not come from a layered matrix, nor were carbon particles present. In addition, the *Cypraea* shell appeared to be naturally beach-worn and concreted, which explains the contents of the shell.

The five pieces of coral were analyzed in the hope of identifying the source of the carbonate material from which the slaked lime had been made. However, we were unable to determine if coral, shell, or some other material had been used to make the lime paste. And although the test results were not conclusive, the aragonitic mineral structure of unburned coral was confirmed.

Artifact Categories and Artifact Function

The two categories of shell artifacts defined and described in this paper consist of gastropod scoops or containers and bivalve scrapers. Both types of artifacts contain variable amounts of the dried, powdery remains of culturally produced slaked lime paste. Although the properties and characteristics of the artifacts and lime deposits have been described, the use of these artifacts can only be inferred. Clearly, the three *Purpura persica* scoops which have been recovered thus far in the Mariana Islands were used to dip lime powder out of a larger container. Given the present day consumption of betel nut with lime in the Mariana Islands, and considering the stained teeth of prehistoric burials recovered from sites on Guam, Rota, and Saipan, it is very likely that the prehistoric populations of the Mariana Islands did chew the betel nut and lime mixture. This would account for both the stained teeth and also the lime–filled gastropod scoops and containers.

However, while *Purpura persica* scoops and *Cypraea tigris* lime containers recovered from Rota and other islands in the Marianas indicate the prehistoric use of betel nut, the probable use of the lime–filled bivalve scrapers cannot be determined as easily. There are two likely functions for the bivalves which account for both their abraded outer surface and utilized scraper edges, and the accumulation of slaked lime powder in their interiors. First, it is possible that the bivalves were used in the production of slaked lime. Perhaps when massive blocks of coral or limestone were burned, the outer oxidized rind of calcium hydroxide was scraped off during the burning process. If this is an accurate account of the use of bivalves in the lime making process, then the bivalve scrapers are not directly related to the consumption of lime and betel nut. Evidence for this behavior could be found among any ethnographic group or archaeological culture having uses for slaked lime. Betel nut would not have to have been known to the prehistoric population for lime filled bivalve scrapers to be present archaeologically.

The second behavior which could account for the abraded and smoothed bivalve exteriors and lime caked interiors is based on field observations made in 1977 by Douglas Yen. Yen observed that the inhabitants of Santa Ana in the southeast Solomons use *Anadara* valves as scrapers and caulking tools in the building of their dugout, plank-sided canoes. After woodworking on the canoe is completed, during the assembly process, "a thick lime preparation is spread over the whole surface, and *Anadara* shells are used to smooth out the lime which is uneven, especially along the caulking lines" (D. Yen, pers. comm.). The same species of bivalve observed in use by Yen is also the most numerous of the lime–filled artifacts recovered from Rota.

Archaeological site reports and ethnographies from western Micronesia were searched for descriptions of lime paste production and use involving bivalve scrapers. While no published accounts were found to corroborate the observations made by Yen, a broad range of slaked lime usage was documented. For instance, various ethnographic sources indicate lime was used for cosmetic and decorative purposes, as a drying agent, and as a cement or caulk. In Truk for instance, where betel nut is rare today and unreported for the period of contact, LeBar (1963: 116) states that a "cement-like caulking compound (*amat*) containing a lime base" was made by burning a mushroom type coral (*foyrup*) in an earth oven. The burned coral was left *in situ,* to slake gradually in the humid air. "When needed, the lime is taken out and pounded. Coconut spathe ashes (*eppinget*) are added to the lime as it is being pounded." The product was used to caulk canoes and to attach sting ray barbs to the shafts of spears.

There are also a number of uses of lime which relate to the manufacture and decoration of ceramics. The "trade ware" of the Mariana Islands identified by Spoehr (1957: 120–121), and the Lapita types of the islands to the south of Micronesia are examples of ceramics having lime–filled or impressed designs. In addition to lime serving as a decorative element, both burned and unburned shell and coral have been used as ceramic tempering agents (Bronitsky & Hamer 1986, Rye 1976, 1981). Table 4 is a summary of some of the most common uses for lime described in the ethnographic literature.

Table 4. Selected references describing the use of slaked lime, taken from the Human Relations Area Files at Southern Illinois University.

Lime use [ingredients]	Island group/area	Reference
Condiment: Consumed with betel and pepper leaf	Yap, Western Micronesia	Senfft 1903:54
Condiment: Spice or food additive	Kurtatchi, Buka NW Solomons	Blackwood 1935:281
Cement: Used to attach sting ray barbs to spears [lime mixed with coconut spathe ashes]	Truk, Central Carolines	LeBar 1963:116
Caulk: Used in canoe building and repair [lime mixed with coconut spathe ashes]	Truk, Central Carolines	LeBar 1963:116
Sealant: Canoe repairs and leak sealant [lime mixed with breadfruit resin]	Truk, Central Carolines	Krämer 1932:234
Sealant: "Putty or mortar" Used to seal lashing holes in canoes [lime mixed with charcoal from coconut husks]	Ifalik, Woleai	Burrows 1949
Glue: Used in assembling canoes [mixture of lime, coconut shell ashes, and juice from pandanus roots]	Woleai, Carolines	Born 1904:181
Plaster: Basic building material [lime mixed with coconut fibers]	Tonga	Vason 1810
Cosmetic: Scalp cleaner and hair stiffener	Tonga	Gifford 1929:232
Dessicant: Used to dry the inside of turtle shells	Lesu, New Ireland	Powdermaker 1933

Although the exact function of the lime–filled bivalves is still unclear, two important points can be drawn from this body of ethnographic data. First, slaked lime was put to a great number of uses by the peoples of Melanesia and Micronesia. In addition to the common use of slaked lime as part of the "betel mixture" (Rivers 1914: 333), lime was consumed directly as a spice or condiment. Lime also served as a cement compound, plaster, cosmetic, and desiccant. Clearly, some artifacts relating to these non-betel uses of slaked lime must remain. This is precisely our second point: in island groups not having the betel palm, lime–encrusted artifacts are still to be expected.

Conclusions

Two types of shell artifacts which are associated with the prehistoric use of slaked lime have been analyzed. The first type consists of gastropods which have been modified to serve as lime scoops or containers. The second artifact type consists of bivalves which show evidence of edge wear and other utilization. Both artifact categories contain variable amounts of slaked lime deposits which are extensively layered in some specimens. While the majority of lime–filled shells are easily identified as artifacts, some of the bivalves appear very similar to naturally broken and concreted shells. Deposits of culturally produced lime contain carbon particles while natural carbonates appear "grainy" and contain coral, sand, and other loosely cemented beach detritus, but no carbon.

The small assemblage of lime–filled artifacts indicates that the past inhabitants of Rota found slaked lime to be useful. The most parsimonious behavioral explanation for the archaeological presence of lime scoops and lime containers suggests the prehistoric use of betel nut. However, the recovery of lime–filled shell artifacts by themselves does not prove they were used only with betel nut. There were many other uses for these artifacts. A number of alternative behavioral patterns, derived from ethnographic sources were noted in this paper. With so many applications for slaked lime reported in the literature, it is clear that lime–filled shell artifacts can be encountered in any Oceanic excavation, not just on islands known to have the "betel mixture."

In addition, we suggest that lime–filled bivalves are not demonstrably part of the betel chewing process. Although the lime paste remaining in the bivalves is chemically identical to that remaining in the gastropods, we believe the bivalves should not be seen as "lime containers" but as special tools. The worn edges and smoothly abraded external surfaces of these shells imply that they served as scrapers. Their normal function may have been as caulking tools in canoe building and repair, or they may have been used more directly in the manufacture of slaked lime. The method of burning large, buried coral heads in Truk (LeBar 1963: 116) and the reported use of block coral in lime production in Palau (K. Blaiyok, pers. comm.) suggests that scraper implements would have been useful. The bivalves may have been used to scrape oxidized lime off of the coral blocks during the burning process. On Rota, it is even possible that these bivalves functioned as tools to shape and smooth latte pillars and capstones, but this is conjecture. Recovery of lime–filled bivalve scrapers in Truk in association with lime burning pits, or from latte quarry areas in the Marianas would help clarify the function of the encrusted bivalve tools.

Acknowledgements

An early version of this paper was presented by the senior author at the Micronesian Archaeology Conference on Guam in September of 1987. Participation in the conference was made possible with financial aid from the Department of Anthropology, the College of Liberal Arts, and the Graduate School of Southern Illinois University at Carbondale. Other assistance was made available by Rosalind Hunter-Anderson, who was responsible for organizing the conference.

The senior author gratefully acknowledges the critical suggestions and support of George Gumerman, Brian Butler, W. Bruce Masse, and David Snyder, all fellow Micronesian archaeologists at Southern Illinois University. Lisa Renken and Pamela Reed at SIU, Katharine Fernstrom (Baltimore Museum of Art), and Michiko Intoh, (formerly at the University of Otago), all read an early draft of this paper. Their comments were much appreciated. Ethnographic data were supplied by Scott Russell on Saipan and Kautchang Vince Blaiyok on Palau. On Guam, conversations with Douglas Yen and Roger Green were especially helpful. Their suggestions and criticisms had a major impact on the final version of this paper. Finally, William Keegan is to be thanked for his role in suggesting this collaboration and then for introducing the coauthors.

References

Blackwood, B. 1935. Both sides of Buka Passage. Clarendon Press, Oxford.

Born, L. 1904. Einige Beobachtungen ethnographischer natur über die Oleai-Inseln. Mitteilungen aus den Deutschen Schutzgebieten, 17: 175–191. Human Relations Area Files, New Haven.

Bronitsky, G., and R. Hamer. 1986. Experiments in ceramic technology: The effects of various tempering materials on impact and thermal-shock resistance. Amer. Antiq. 51: 89–101.

Burrows, E. G. 1949. The people of Ifalik: A little disturbed atoll culture. Typescript, unpublished (Coordinated Investigation of Micronesian Anthropology, Pacific Science Board, NRC). Human Relations Area Files, New Haven.

Butler, B. M. 1988. Archaeological investigations on the north coast of Rota, Mariana Islands. Occasional Paper 8. Center for Archaeological Investigations. Southern Illinois University at Carbondale.

Carucci, J. 1988. Nontool marine shell. *In* B. M. Butler (ed.), Archaeological Investigations on the North Coast of Rota, Mariana Islands, pp. 301–334. Center for Archaeological Investigations Occasional Paper 8. Southern Illinois University at Carbondale.

Chen, P.-Y. 1977. Table of key lines in X-ray powder diffraction patterns of minerals in clays and associated rocks. Geological Survey Occasional Paper 21, Department of Natural Resources, Indiana Geological Survey, Bloomington.

Dance, S. P. 1976. The Collector's Encyclopedia of Shells. McGraw-Hill, New York.

Gifford, E. W. 1929. Tongan Society. Bernice P. Bishop Musuem, Honolulu.

Gifford, E. W. & D. S. Gifford. 1959. Archaeological Investigations in Yap. Anthropological Records 18: 2, University of California, Berkeley.

King, T. F. & P. L. Parker. 1984. Pisekin noomw noon Tonaachaw; Archaeology in the Tonaachaw Historic District, Moen Island. Center for Archaeological Investigations Occasional Paper 3. Southern Illinois University at Carbondale.

Krämer, A. 1932. Truk. Hamburg, Friederichsen, de Gruyter. Human Relations Area Files, New Haven.

LeBar, F. M. 1963. The material culture of Truk. Human Relations Area Files, New Haven.

Milliman, J. D. 1974. Marine Carbonates. (Part 1 of Recent Sedimentary Carbonates by J. D. Milliman, G. Muller & U. Forstner). Springer-Verlag, New York.

Powdermaker, H. 1933. Life in Lesu: The Study of a Melanesian Society in New Ireland. Norton, New York.

Randall, R. H. & R. F. Myers. 1983. Guide to the Coastal Resources of Guam, 2: The Corals. University of Guam Press.

Ray, E. R. 1981. The material culture of prehistoric Tarague Beach, Guam. Masters Thesis, Arizona State University.

Reinman, F. R. 1977. An archaeological survey and preliminary test excavations on the island of Guam, Marianas Islands, 1965–1966. Misc. Pub. 1, Micronesian Area Research Center, University of Guam.

Rivers, W. H. 1914. Tikopia. *In* The History of Melanesian Society, 1. Cambridge University Press.

Rye, O. S. 1976. Keeping your temper under control: Materials and the manufacture of Papuan pottery. Archaeol. & Phys. Anthropol. in Oceania 11: 106–137.

Rye, O. 1981. Pottery Technology: Principles and Reconstruction. Manuals on Archaeology 4. Taraxacum, Washington.

Senfft, A. 1903. Ethnographische Beitrage uber die Karolineninsel Yap. Petermans Mitteilungen, 49: 49–60, 83–87. Human Relations Area Files translation, New Haven.

Shepard, A. O. 1956. Ceramics for the Archaeologist. Carnegie Institution of Washington, Publication 609. Washington, D.C.

Spoehr, A. 1957. Marianas Prehistory: Archaeological Survey and Excavations on Saipan, Tinian, and Rota. Fieldiana: Anthropology 48, Chicago.

Thomas, W. L., Jr. 1965. The variety of physical environments among Pacific Islands. *In* F. R. Fosberg (ed.), Man's Place in the Island Ecosystem, pp. 5–37. Bishop Museum Press, Honolulu.

Tite, M. S. 1972. Methods of Physical Examination in Archaeology. Seminar Press, London.

Vason, G. 1810 An authentic narrative of four years' residence at Tongataboo, one of the Friendly Islands, in the South-sea, by ——— who went thither in the Duff, under Captain Wilson in 1796. Longman, Hurst & Rees, London.