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Status, Health, and Ancestry of a Late Prehistoric Burial from Kwajalein Atoll, Marshall Islands

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Abstract—A bioarchaeological study is presented for a chronometrically-dated human burial from the Marshall Islands. Associated with 151 grave goods, the artifacts imply the individual's relatively high status and point to prehistoric long-distance contacts between the Kwajalein community and distant island groups. The burial is a male, about 30 to 40 years of age at time of death, and in generally good health. There is no evidence for cause of death. MtDNA analysis, applied to prehistoric human remains from the Marshalls for the first time, raises the possibility that lineages similar to the dominant one from the Marianas may have been more widespread in other parts of Micronesia. This may indicate a recent expansion of Lineage Group I, currently the most common throughout Micronesia, and confirms the complexity of Micronesian colonization and post-settlement histories.

Introduction

Recent summaries of Micronesian bioanthropology have lamented the lack of adequate well-provenanced skeletal samples from the geographic breadth of the region (Hanson & Pietrusewsky 1997, Pietrusewsky 1990a). Most of what we know about prehistoric Micronesians is from the Mariana Islands due to contract archaeology related to economic expansion and capital improvements during the past 15 years (Hanson & Pietrusewsky 1997: 267). The emphasis on the Mariana Islands has greatly increased our biocultural perspective on its prehistory (Hanson & Butler 1997), but a void continues by the relative lack of public-funded, development-oriented archaeology and purely research-driven pursuits in the vast Caroline Islands. Larger and better provenanced samples of human remains from Micronesia are needed for studying “microevolutionary changes, health, nutritional standards, demography, and socioeconomic status for now deceased populations” (Pietrusewsky 1990a: 319). We seek to augment the scant paleoanthropological data for extra-Marianas contexts by analyzing a late prehistoric burial from Kwajalein Atoll, Marshall Islands. This is a directly-dated interment with 151 grave goods. General health, stature, age at death, and social status are assessed. This first mtDNA study of prehistoric Marshallese human remains provides insights into the origins of these atoll dwellers situated in the extreme eastern margin of Micronesia. In an area with few regionally-diagnostic artifacts and a poorly-resolved radiocarbon chronology, skeletal remains may be the best link to understanding the human colonization and post-settlement histories in the Marshalls and, indeed throughout eastern Micronesia.

Consisting of 29 low coral atolls and five small coral islands spread over nearly 2 million km^2 of ocean, the Marshall Islands are the most dispersed set of islands in the Pacific. Located about 4,000 km southwest of Hawai‘i, the islands form two roughly parallel alignments oriented northwest-southeast with Kwajalein Atoll situated near the center of the Ralik Chain (Fig. 1). Ranging from 4˚ to 12˚ north latitude, a marked rainfall gradient from 500 mm in the dry north to 3000 mm in the wet south influenced prehistoric economies and is reflected in atoll settlement patterns and subsistence practices. While coconut is omnipresent, pandanus is more important in the northern atolls and cultivation of the salt-tolerant aroid, *Cyrtosperma*, is widespread in the wet south (Weisler 1999a). Breadfruit obtains greater importance for the middle and southern atolls. While today the government is the major employer in the capital at Majuro Atoll, the U. S. military base at Kwajalein Atoll is the dominant source of revenue there. On the outer atolls, however, copra production is the primary source of cash for the semi-subsistence lifestyle. Daily fishing augments a diet of canned meats, flour, and rice.

A single human burial was discovered in June, 1994, by employees of Johnson Controls World Services who were contracted to excavate trenches for underground utilities on the Kwajalein military installation. Unfortunately, upon discovery of the interment, backhoe operators removed much of the *in situ* bone from the burial pit. Marshall Weisler, accompanied by Carmen Bigler and Hemley Benjamin of the Historic Preservation Office, Republic of the Marshall Islands (HPO-RMI), conducted two days of on-site investigations. The 135 m long trench, previously excavated by backhoe to a depth of 110 cm and 90 cm wide,

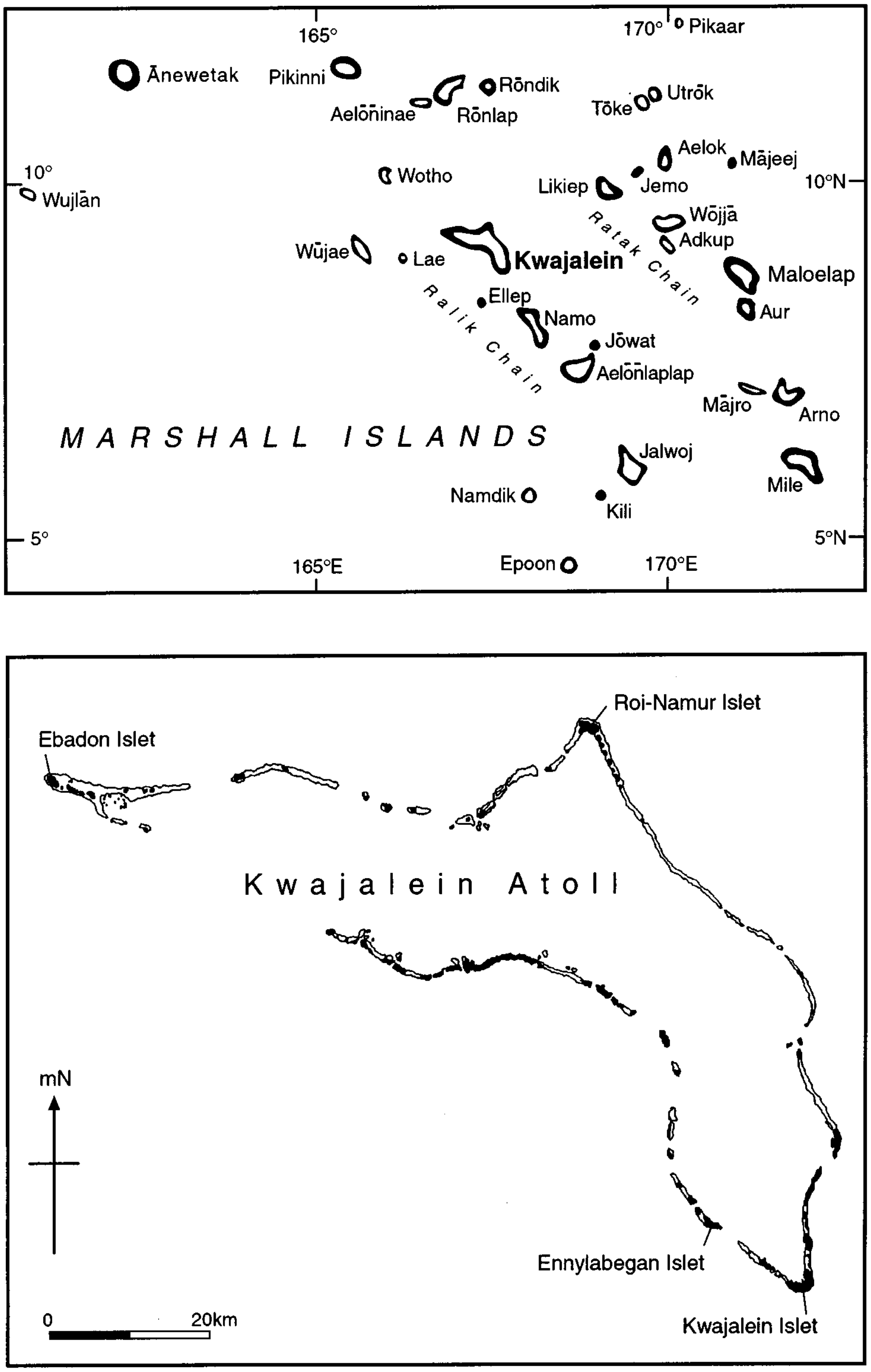

Figure 1. Maps of the Marshall Islands and Kwajalein Atoll.

was examined for *in situ* cultural material. The spoil dirt associated with the burial was screened with 6.4 mm (1/4") mesh sieves and all prehistoric cultural material retained. Sara Collins analyzed the human bones, while J. Koji Lum and Wayne S. Kimoto performed mtDNA studies. All human bones and artifacts are currently stored at the HPO-RMI.

Previous Archaeological Research

The origins and earliest dates for colonization and settlement of the Marshall Islands are unresolved issues. Linguistics have provided some useful models suggesting founding groups originating in eastern Melanesia, perhaps Vanuatu and the eastern Solomons (Marck 1975). Canoe voyage simulations by Irwin (1992) supports the linguistic models, but also suggests alternatives such as a "steppingstone" trail from Fiji north through the low coral atolls of Tuvalu and Kiribati, then into the southern Marshalls. The low-fired, shell-tempered ceramic technology of the high islands of eastern Micronesia (Chuuk, Pohnpei, and Korsae) have broad similarities with late Lapita pottery of the Bismarcks and eastern Solomons (Kirch 1997:76) which also share stylist affinities (Athens 1990, Ayres 1990).

Chronometric dating has provided more controversy than resolution for establishing the human colonization of the Marshall Islands. Considering island emergence and sea level fluctuations (Nunn 1994), one would hardly expect that the low coral atolls had sufficient dry land to support permanent human colonists much before 2000 BP. However, Streck has reported three radiocarbon age determinations on unidentified wood charcoal from Bikini Atoll at 2380, 2575, and 3450 BP (Streck 1990:255). While these dates may provide the correct ages of the wood, we do not know the relationship of the samples to well-documented archaeological events. There are, however, a suite of well-documented dates, from several atolls, at or near 2000 BP. Shun & Athens (1990: 236) dated a suspected developed taro swamp on Kwajalein Atoll, Riley (1987: 242) has a comparable date from an earth oven on Majuro Atoll, while Weisler (unpublished; Weisler 1999a) has several dates in the 1800–2000 BP age range from settlement pattern surveys and excavations on Ebon, Maloelap, and Utrōk atolls.

Marshall Islands archaeology remains in the "exploratory" phase and it is only possible to discuss ahistorical atoll settlement patterns; no archipelago-wide cultural-historical framework has yet been proposed. As part of the multi-year Kelton-Bishop Museum expedition to the Marshall Islands and eastern Micronesia, Rosendahl (1987) conducted the first reconnaissance-level surveys in the Marshalls to evaluate the potential for archaeological research. Some 42 sites were recorded on 12 atolls; 15 test pits were excavated at eight sites on four atolls and more than 4,000 portable artifacts were collected, mostly from surface contexts. Following a year later in 1979, Riley (1987) conducted a detailed settlement pattern survey of Majuro Atoll. He grouped sites into midden areas, house platforms, coral-faced structures, fishtraps, wells, and defined a *Cyrtosperma* pit zone in the interior of the largest islet. He suggested that the oldest portion of a

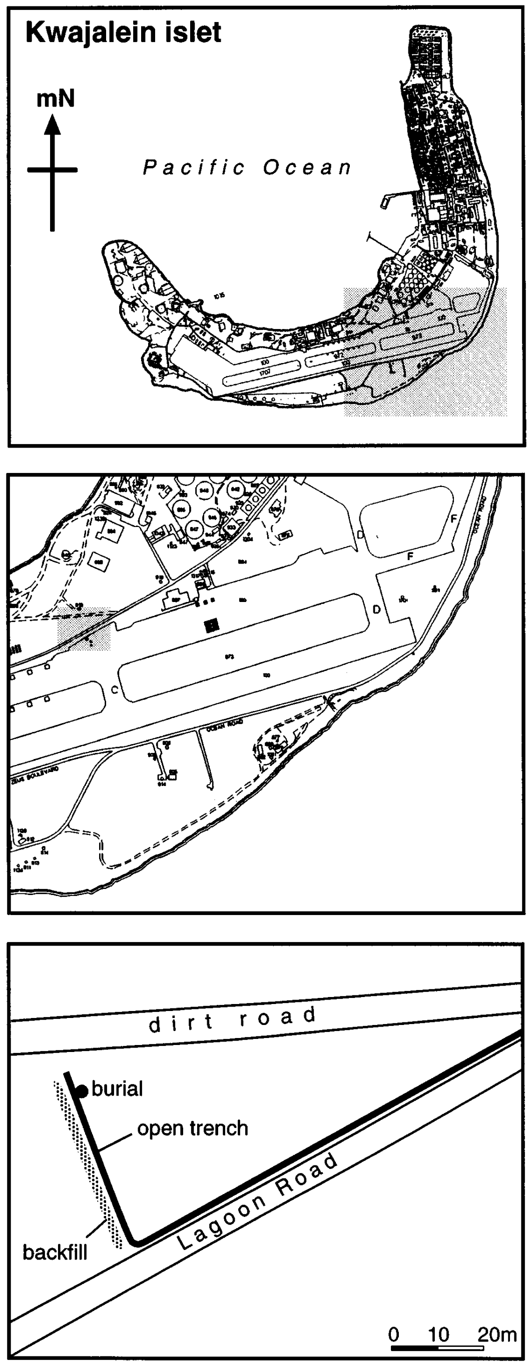

Figure 2. Map of Kwajalein islet and archaeological site Mi-MLKw-1 showing backhoe trench, backfill, and location of burial.

habitation site should be in the middle of an islet as the landform builds towards the lagoon (see also Hatheway 1953: 53). In 1980, Dye continued the focus on atoll settlement patterns with his survey of Arno, located just a short distance east of Majuro. He used surface and systematic transect excavations to search for buried sites, finding 164 locales on 133 islets (Dye 1987). Smaller, contract-related projects were completed on Kwajalein (Beardsley 1994, Shun & Athens 1990) and Bikini atolls (Streck 1990). Weisler (1999b) surveyed Ujae Atoll, identifying three habitation sites, an aroid pit agricultural zone, early historic burials, and seven fish traps, weirs, and enclosures. Thirty-five portable artifacts, more than 4,000 faunal specimens, and nearly 13 kg of shellfish were recovered from 8 m^2 of excavation. Radiocarbon age determinations document habitation as early as the third century AD.

Few human burials have been discovered and carefully excavated in the Marshalls. Indeed, a previous study of seven Marshallese male crania used museum specimens collected during the late 19th and early 20th centuries without detailed documentation (Pietrusewsky 1990b). Investigations of 29 burials at Laura village, Majuro Atoll was, in a classic sense, a salvage-rescue archaeological project where “most of the bones were badly broken due to construction vehicle traffic” (Spennemann 1994: 32) as part of a groundwater development project.

Archaeological Context

Kwajalein islet was the scene of intense military operations during World War II (Crowl & Love 1993) which included aerial bombing, bulldozing, and trenching, but much of the subsurface prehistoric deposits are intact. Construction in the early 1980s of the Kwajalein airfield revealed 2,000 year old subsurface cultural deposits and a suspected gardening layer, as well as a range of prehistoric domestic artifacts and food remains (Beardsley 1994). This evidence is consistent with findings on other atolls where substantial prehistoric habitation areas are located near the center of the largest islets of an atoll. Furthermore, prehistoric and historic burial areas are often situated lagoonward of major village sites. This appears to be the case with the burial reported here which was located on the lagoon side (northwest shore) of Kwajalein islet, Kwajalein Atoll and designated site Mi-MLKw-1 (hereafter, site 1) by the Historic Preservation Office, Republic of the Marshall Islands (Fig. 2). Craib (personal communication to the HPO-RMI) reported a prehistoric burial in the general vicinity of site 1 and it is likely that these two, seemingly isolated, burials may represent an interment area.

Stratigraphy and Burial Pit Context

Located about 100 m from the lagoon shore, the bottom of the site 1 burial was located 95 cm below surface and less than 1 m above the high tide mark. The burial pit was originally excavated into culturally sterile, very pale brown (Munsell, 10YR 8/4), well-sorted, medium-texture beach sand designated layer IV (Fig. 3). The pit dimensions were 165 cm long, 55 cm deep, and estimated to be at least 60 cm wide. (Because the interment was cut by the construction trench, it is not possible to determine the precise width of the burial pit.) The top of the pit was probably scraped flat by a bulldozer some decades ago, possibly after wartime activities (see Fig. 3). The interment was then capped by layer III, a culturally sterile, dark gray (10YR 4/1), well sorted, medium-texture beach sand. The dark gray color is due to the formation of an A horizon whereby the development of plant material darkened an otherwise lighter sand. The upper layers I and II may represent bulldozing and grading activity as these deposits are poorly sorted pebbles and cobbles within a matrix of very coarse sand. Here, the difference between layers I and II is primarily the darker sediment color, caused by the development of the A horizon.

It is difficult to determine precisely the alignment and burial position of the interment due to its highly disturbed context. However, the individual was buried with the long axis oriented northwest-southeast, the head situated towards the lagoon. Judging from the few *in situ* bones and the length of the burial pit, it was probably an extended burial. Numerous grave goods were found in the trench back-dirt and several were found *in situ* (Fig. 3). These are described below after a discussion of dating.

Dating Methods and Results

There have been no directly dated human burials from the Marshall Islands, consequently, we viewed chronometric dating of the Kwajalein interment as a primary objective. Portions of a femur and fibula, with a total weight of 333.0 grams, were submitted to Beta Analytic Inc. (Florida) for radiocarbon dating and stable isotopes ($^{13}C/^{12}C$) analysis of the collagen fraction. All dating procedures went normally. The conventional ^{14}C age results of sample Beta-79502 are 390 ± 50 BP calibrated (after Stuiver & Reimer 1993), at 2 sigma, to AD 1429-1645, with a mean of AD 1486. This mean date is considered late prehistoric since early historic contact with the Marshall Islands was in the beginning decades of the 16th century (Hezel 1983) with more significant contacts documented nearly three centuries later (Chamisso 1986).

Artifacts

Associated with the Kwajalein burial were 151 shell ornaments. The most numerous were disk beads made from the large *Spondylus* cf. *varius* bivalve. Modern bivalves of this taxon are not known from the Marshall Islands, although subfossil material has been recovered from archaeological contexts on Ebon Atoll, where residents believe the species is extinct. Indeed, today, *S. varius* is rare in the Tuamotus (Salvat & Rives 1975: 370). In Kiribati, the atoll island group south of the Marshalls, large *Spondylus* were regarded by islanders as having a mysterious origin as shells were found only rarely. Pendants made from large *Spondylus* were among the most valuable ornaments a family possess and were heirlooms (Koch 1986: 159). Chuukese informants relate that *Spondylus* beads (*föyppar*) and disks were imported from the Mortlock Islands to the south (LeBar

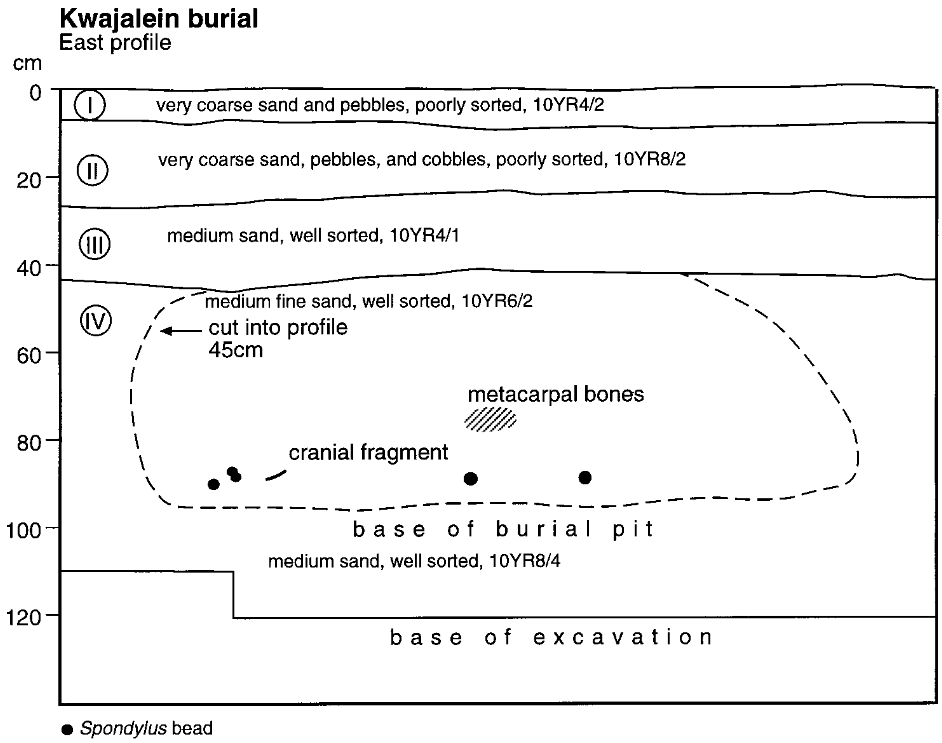

Figure 3. Stratigraphic section showing position of burial pit, *in situ* human bones and artifacts.

1964: 159, 164). Butler & Harris (1995:249-250) report *Spondylus* disks from late prehistoric contexts (late Transitional to Latte Period) on Saipan and suggest that *Cypraea* and *Conus* beads are early, while *Spondylus* disks are late markers. In the Marshall Islands, large *Spondylus* disks are known from surface contexts on Ailinglaplap and Majuro atolls (Rosendahl 1987:Fig. 174d and f) and one was recovered from recent excavations on Utrōk Atoll.

The 147 beads were sorted into taphonomic groups based on preservation: Group 1 (n = 17, 11.6%) were the best preserved, had sharp edge definition and robust color (Munsell 5R 6/6, light red) (Fig. 4:b); Group 2 (n = 73, 49.7%) exhibited some color loss to white with slight erosion evident (Fig. 4:a); Group 3 (n = 42, 28.6%) were all white with chipped edges (Fig. 4: d); and Group 4 (n = 15, 10.2%) were very eroded, thin, and had poor edge definition (Fig. 4: c). The range of disk bead preservation implies that not all specimens were manufactured at once and, perhaps, were collected or gifted over a long period of time. Metric attributes for 90 measurable specimens are: diameter 19.3 ± 2.02 mm (range 14.73–22.88 mm); thickness 1.99 ± 0.33 mm (range 1.09–2.33 mm); weight 1.3 ± 0.42 grams (range 0.38–2.33 g). Most specimens were biconically drilled, although a few were drilled completely through from one side. Of the 146 whole beads, just over half had holes drilled in the center, while 66 (45%) of holes were

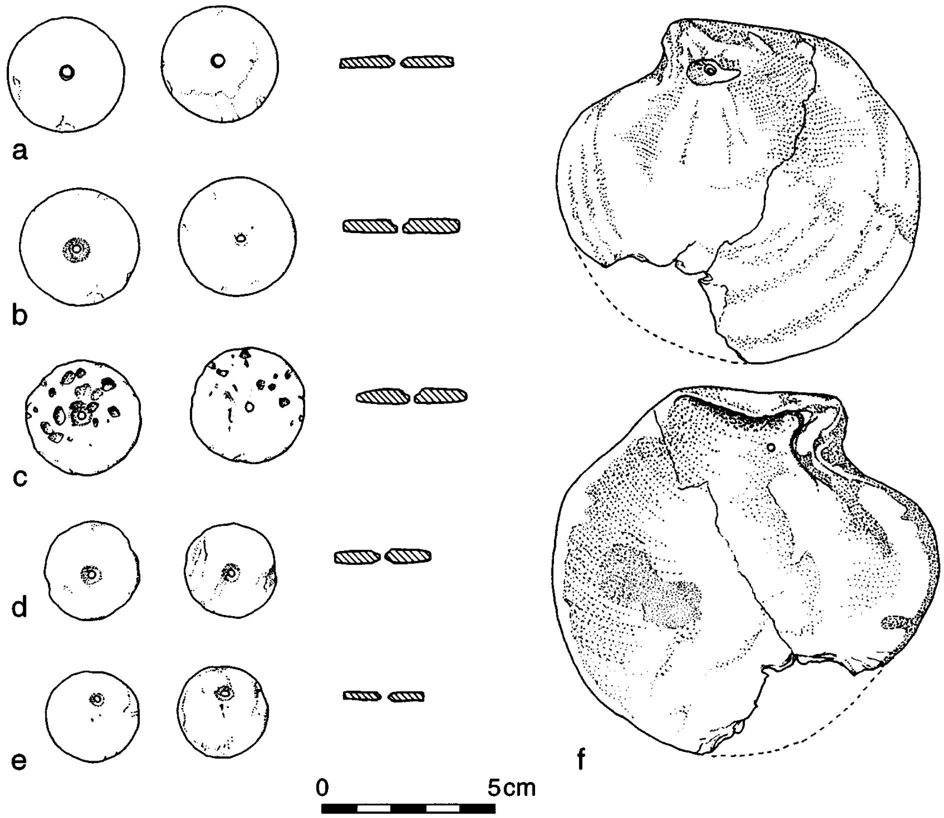

Figure 4. *Spondylus* disks illustrating the range of preservation and the polished *Pinctada margaritifera* valve with drilled hole near the hinge.

off-center (Fig. 4: e). The drilled hole of all beads had a minimum diameter of 2.07 ± 0.39 mm and maximum of 3.44 ± 0.74 mm. The overall range was 1.35–5.59 mm.

Three *Conus* shell rings were pieced together from fragments recovered in the trench spoil dirt. These ornaments were probably manufactured from *Conus leopardus*, the largest species. Although most commonly thought to be worn on the upper and lower arms, they may also have been worn as ear ornaments placed within greatly distended lobes (Moss 1889: figure following page 126). *Conus* shell rings reported from the Marshall Islands are either quite narrow with plano-convex to lenticular cross-sections or relatively wide, rectangular in cross-section, with or without incised parallel grooves or raised rims (Rosendahl 1987: figs 1.75 and 1.76). The wider styles, similar to those recovered from Kwajalein, were the likely forms used for ear ornaments. Design on the Kwajalein *Conus* rings is minimal, but consists of slightly raised, parallel rims along the exterior edges, best seen in the side views in figure 5: c. Perhaps the raised rims are a

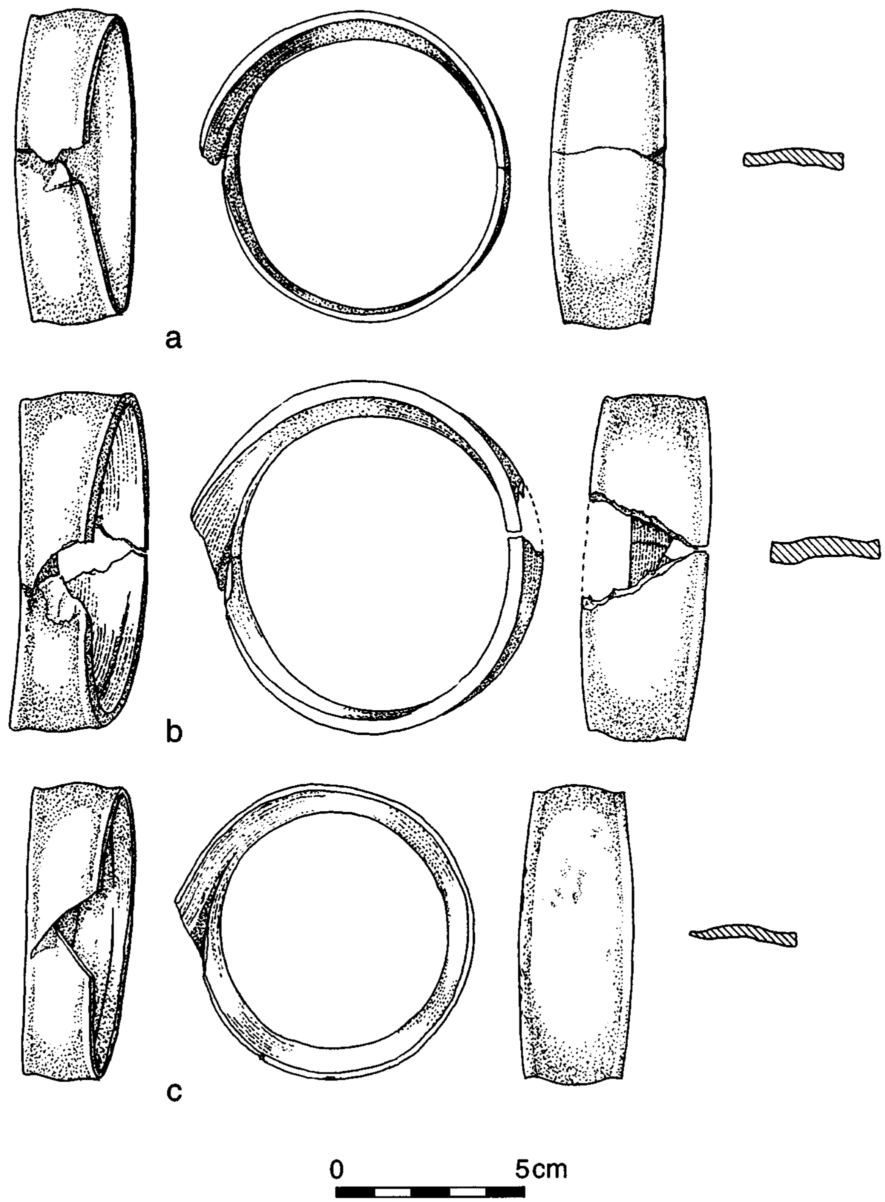

Figure 5. *Conus* shell rings.

functional attribute which helped to secure the ornaments within the ear lobes. Exterior diameters of the rings reported here are: 74.98, 80.35, and 89.73 mm and interior diameters are: 62.80, 70.23, and 80.09 mm. Widths are 27.37, 29.25, and 30.79 mm.

Polished *Pinctada* valves, worn as breast ornaments, are known from the Tuamotu, Society, and Cook Islands (e.g., Buck 1944: 117–123) with the specimen from site 1 similar to one from Pukapuka in the northern Cooks (Beaglehole & Beaglehole 1938: 156). The exterior surface of a small *Pinctada margaritifera* valve was removed to expose the lustrous nacreous interior. A small drill hole near the hinge facilitated suspension of this ornament, possibly around the neck (Fig. 4: f).

Osteological Analysis

The human remains were collected *in situ* from the burial pit, while the majority of bone was retrieved from sieving the back-dirt dispersed along about 5 m of the trench. The bones, however, were clearly from the same individual.

Methods and Materials

The remains were received from the Republic of the Marshall Islands Historic Preservation Office (RMI-HPO), and underwent macro-analysis at a private laboratory in Honolulu, Hawai‘i. The bones were dry-brushed clean of adhering sand and rootlets, and laid out in anatomical order. Where possible, temporary mending of postmortem breaks was accomplished with water-soluble glue and surgical tape. All measurements were taken using Swiss-made coordinate calipers, dial spreading calipers, and/or osteometric tape; a standard osteometric board was used to record maximum lengths of intact long bones.

Due to the circumstances of its discovery, the remains of the individual sustained significant damage, yet many portions of the cranial and infracranial regions of the skeleton were recovered. In general, although the bone was fragmentary it was well-preserved, completely macerated, and with little cortical exfoliation; no doubt, its original interment in calcareous sands enhanced the preservation of the bone. The recovered remains are derived from one individual; the atlas vertebra articulates with the basicranium, and morpho-metric data obtained from the infracranial remains indicate that only one individual is represented. Unfortunately, the degree of postmortem damage was such that the cranial vault could not be reconstructed although a number of non-metric observations could be made. Figure 6 provides a schematic diagram of skeletal completeness for the Kwajalein remains while Table 1 lists the identifiable skeletal and dental remains. The dental remains were also incomplete but displayed some antemortem tooth loss as well as postmortem damage due to the construction activities. Figure 7 is a schematic illustration of the Kwajalein dental remains. The teeth are all adult dentition and are coded numerically, as recommended by Buikstra and Ubelaker (1994).

Biological Characteristics

The general morphology of the maxillary portions and mandible indicate a Mongoloid ancestry; in particular, the parabolic shape of the maxillary dental arch

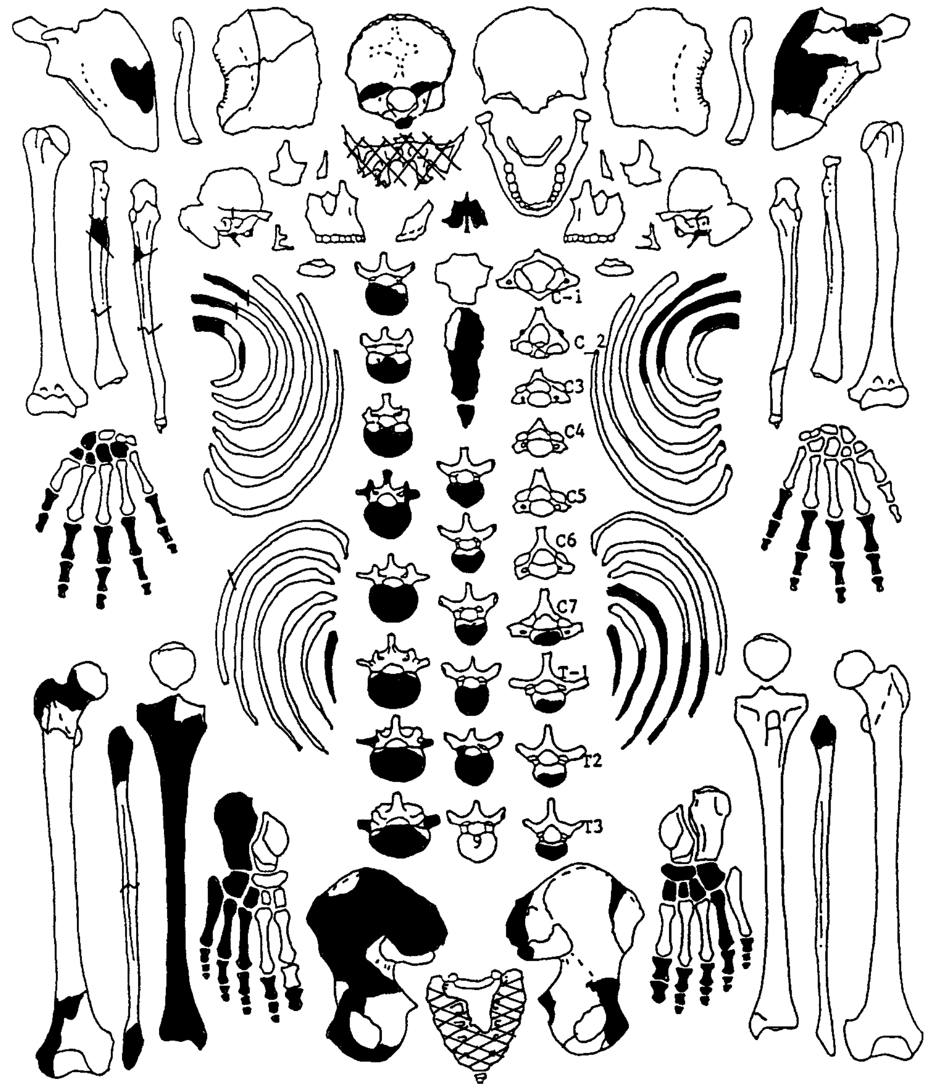

Figure 6. Schematic diagram illustrating skeletal completeness of the Kwajalein burial.

and presence of markedly shovel-shaped incisors suggest such an ancestry (Rhine 1990). The unusually robust appearance of the mandibular corpus and the upright, wide ascending rami further suggesting a biological affinity with Micronesian populations as do the presence of slightly developed occipital superstructures (Heathcoate et al. 1996, Sava 1995).

Cranial morphology—particularly the well-marked supraorbital and occipital ridges, mastoids, and robust mandible—indicate the male sex. Pelvic

Table 1. List of identifiable skeletal and dental remains recovered from the Kwajalein burial.

Cranial region
Cranial vault portions including fragments of the frontal, right and left parietal and temporal bones, and occipital squamous and basi-occiput; sphenoid and ethmoid are highly fragmented; Right and left maxillary portions; mandible.

Axial Skeleton
Right and left clavicles, portions of right and left scapulae; vertebrae C1–C6 intact, vertebrae C7, T1–T8 have spinous processes only, vertebra T9 is missing; vertebrae T10–T12, L1–L5 have spinous processes only; sacrum is fragmentary; portions of all right ribs except #12 which is missing, portions of all left ribs except #10 and 12, which are missing; fragments of right and left innominate.

Appendicular Skeleton
Major portions of right and left humeri, radii, and ulnae; portions of right femur and fibula, and a proximal end fragment of right tibia; intact left femur and tibia, nearly complete left fibula (lacks proximal end); right and left scaphoids, lunates, and trapeziums; left triquetrum, hamate, and capitate; proximal phalanges of all right and left fingers; right and left patellae; right and left tali; right navicular, first and second cuneiforms, first and second metatarsals; left first, second, third, and fifth metatarsals.

Dental Remains
Maxillary dentition: #1 lost antemortem, #2 present, #3 lost antemortem, #4 present, #5 lost antemortem, #6 –7 present, #8 lost antemortem, #9–11 present, #12 lost antemortem, #13 present, #14 lost antemortem, #15–16 lost postmortem. Mandibular dentition: #17 present, #18 lost antemortem, #19–20 present, #21 lost antemortem, #22–27 present, #28 roots only present, #29–30 present, #31–32 lost antemortem.

morphology is male and the robust muscle markings and attachments on the long bones also indicate the male sex.

The individual represented in the Kwajalein burial is skeletally adult. The epiphyses of all long bones present are fused, as are the later-fusing epiphyses present in the remains, like the medial clavicular epiphysis, the iliac crest of the innominate, the superior and inferior epiphyseal rings of the vertebral centra, and the rib heads. With one exception (tooth #17), the third molars erupted and were lost antemortem, as indicated by alveolar resorption. Skeletal sites that offer narrower age ranges in the adult (sternal ends of ribs or pubic symphysis) were not sufficiently well-preserved or complete to use. Taken together, the available ageing data support a lower range of at least the late 20s and an upper range of the mid- or late 30s.

The maximum length of the intact left tibia (36.0 cm) was used in the appropriate regression equation for Mongoloid males by Trotter (1970) to obtain a stature estimate of 167.5 cm (± a standard error of the estimate of 3.27 cm), or just under 66".

The Kwajalein skeletal remains had few signs of pathology, and those largely derived from normal ageing processes. The metacarpals and proximal phalanges of the fingers showed the beginnings of degenerative bony changes, with osteophytes present along their palmar surfaces. The right and left scaphoids and

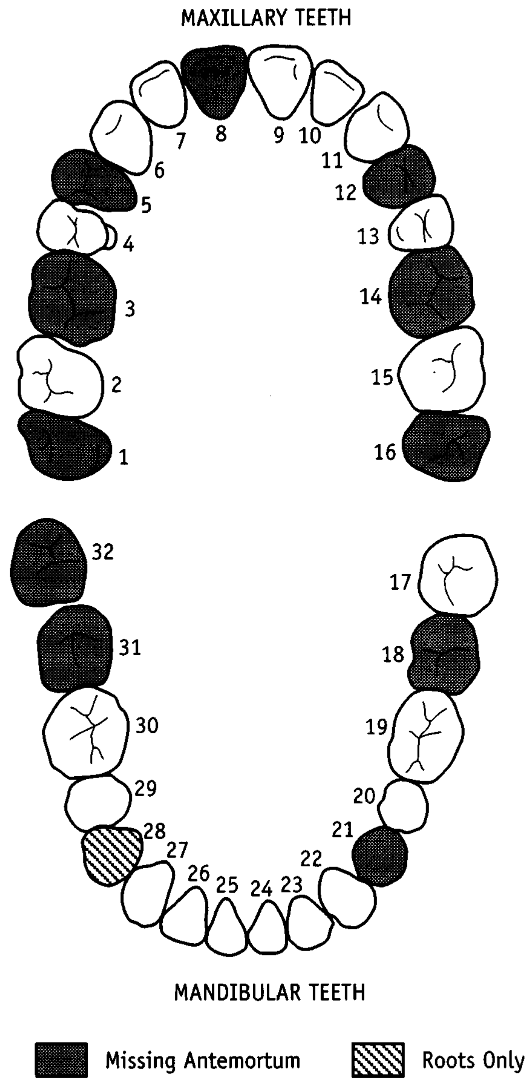

Figure 7. Schematic diagram illustrating dental completeness of the Kwajalein burial.

trapeziums also displayed slight development of osteophytes The patellae also exhibited slight spurring on the anterior surface. Pathology in the dental remains consisted of dental caries and antemortem loss of some teeth; in particular, teeth #13, 17, and 28 exhibited large occlusal caries. In the instances of antemortem tooth loss, several of the tooth sockets had undergone alveolar resorption. No abscesses were visible. Occlusal wear and calculus were present in slight amounts on most teeth; no signs of enamel hypoplasia were evident.

The incomplete remains prevented some non-metric observations from being made but the following data were recorded. In the cranial portions present, perhaps the most notable feature was the presence of slightly developed supermastoidal tubercles on the right and left sides. Scored at a slight-moderate state, the feature was expressed as a mounded rather than tuberculated swelling on both sides; they each measured slightly less than 2 mm high from the parietal squamous surface immediately superior to each tubercle. Table 2 presents the cranial non-metric data recorded from the Kwajalein remains.

In the infracranial skeleton, morphological variation was within normal parameters, and there were no remarkable observations. Table 3 provides the observations made on non-metric infracranial variation in the long bones, while Tables 4 and 5 provide data on non-metric and pathological observations on the cervical, thoracic, and lumbar vertebrae.

Although the Kwajalein remains sustained a significant amount of postmortem damage, a number of standard metric observations could be made, particularly from the dentition and the infracranial skeleton. Table 6 contains a summary of metric data collected from the infracranial skeleton while Tables 7 and 8 provide measurements of the mandibular remains, and the teeth.

In summary, the burial was an adult male, perhaps 30 to 40 years of age at the time of death. His age at death is within the life expectancies at birth for the large Mariana Islands samples which range from 26.4 to 33.7 years (Hanson & Pietrusewsky 1997:268). His bones had well-marked muscle attachments, indicating that he led a strenuous life, regularly performing tasks or activities that required flexing of the knees. Slight degenerative changes (bony spurring) was seen on finger bones, patellae (knees), and left tibia, the latter possibly of traumatic origin. Severe caries were noted on some upper and lower teeth and antemortem loss of eight upper and lower teeth was documented. The amount of dental decay and before-death tooth loss may be caused by dietary deficiencies like those observed in some ancient remains from Rota (Hanson 1990). The lack of extensive tooth wear suggests that foods were relatively soft and easy to eat and perhaps high in carbohydrate and/or sugar content. Stature was determined by measuring the intact left tibia and was calculated at 166.1 ± 3.27 cm (65.4 ± 1.3"). In general, the man appears to have been healthy and there is no indication of the cause of death.

MtDNA Analysis

Materials and Methods

We had two bone selection criteria. The ideal bone must be intact to minimize potential contamination from surrounding microbes, and it should be relatively small and thus easy to work with. These criteria were met by a complete calcaneus which was sacrificed for mtDNA analysis. First, the outer surface of the bone was removed with autoclaved and UV sterilized sandpaper. The remaining material was then wrapped in ten layers of autoclaved aluminum foil and

Table 2. Non-metric traits of the Kwajalein burial.

Bilaterial Traits	Left	Right
Frontal grooves	absent	absent
Supraorbital structure	absent	absent
Spina trochlea	present	present
Intraorbital foramen	single	single
Zygo-facial foramen	single	double
Infraorbital suture	single	single
Multiple ethmoidal foramina	-	-
Marginal tubercle	slight	slight
Os japonicum	absent	absent
Maxillary torus	absent	absent
Pterygo-spinous bridge	-	-
Ovale-spinosum	-	-
Anterior condylar canal	-	-
Posterior condylar canal	-	-
Paramastoid	-	-
Mastoid suture	present	present
Occipital superstructures	slight-moderate	slight-moderate
Mastoid suture extrasutural	occipito-mastoid	occipito-mastoid
Cribra orbitalia	absent	absent
Parietal foramen	single	single
Asterionic bone	-	-
Coronal wormian	-	-
Lambdoidal wormian	-	-
Pterion	-	-
Parietal notch	-	-
Asterionic bone	-	-
Tympanic thickening	absent	absent
Tympanic dehiscence	absent	absent
Tympanic marginal foramen	absent	absent
Auditory exostoses	absent	absent
Mandibular torus	absent	absent
Mylohyoid bridge	absent	absent
Multiple mandibular foramen	absent	absent
Ramus shape (coronoid:condyle)	equal	equal
Single Trait	**Observation**	
Metopic suture	trace	
Nasal frontal suture	-	
Nasal bone shape	-	
Nasal suture deflection	-	
Subnasal	sharp	
Palatine torus	absent	
Precondylar	-	
Jugular foramen asymmetry	-	
Pharyngeal fossa	-	
Ossified apical	-	
Bregmatic bone	absent	
Sagittal wormian	seven	
Lambdic bone	absent	
Vault form (posterior)	-	
Sagittal keeling	-	

Occipital form	ridge
Sagittal-bregmatic deflection	-
Rocker jaw	absent
Chin form	median-bilateral

equilibrated in a –80º C freezer for 30 minutes. The frozen bone was then pulverized using a standard carpenter's hammer (Craftsman). Multiple DNA extractions were performed using 250–350 mg portions of the powdered calcaneus using the protocol of Boom et al. (1990). A negative extraction control containing all reagents but without bone was performed in parallel. All pipetting during the extractions employed aerosol resistant tips (Molecular Bio-Products) and the setting up of polymerase chain reactions (PCR) used positive-displacement pipettes (Gilson) in order to minimize the possibility of contamination from modern sources.

Five µL aloquots of the 120 µL extract were used as template to amplify a portion of the mtDNA Hypervariable segment I (HVSI) in two PCRs. The first PCR included primers L15997 (5'-biotin-CACCATTAGCACCCAAAGCT-3') and H16401 (5'-TGATTTCACGGAGGATGGTG-3') (Operon Technologies). Two µL of the first reaction were used in a second PCR including L15997 and an internal primer H16321 (5'-TGTGCTATGTACGGTAAATG-3'). PCR reactions were performed in 50 µL volumes in a DNA Thermocycler 480 (Perkin Elmer Cetus). Each PCR reaction contained 12.5 mM each deoxynucleoside triphosphate, 250 pM of each primer, and 3 units of Taq polymerase (Promega). Each PCR began with a 2 minute, 94º C hot start employing HotStart 50 reaction tubes (Molecular Bio-Products), followed by 92º C for 30 seconds, 55º C for 30 seconds and 72º C for 30 seconds repeated for 36 cycles. After the last cycle a final 10 minute extension at 72º C was performed. PCRs were also attempted from both the extraction blank and distilled water to control for contamination of reagents. Neither of the negative controls yielded amplification products.

The bone extract yielded a product of the expected size after the second PCR. This product was purified using strepavidin coated magnetic beads (DYNAL) and sequenced directly using ^{35}S dATP (Amersham) and the Sequenase kit (U. S. Biochemical). MtDNA sequences were generated from J. K. Lum and W. Kimoto who handled the bone sample in the laboratory to control for contamination during extraction. These sequences were distinct from the sequence amplified from the bone extract.

Results

Figure 8 displays 195 bases of unambiguous sequence generated repeatedly from the Kwajalein bone extract. The numbers indicate the location of the region sequenced within the mtDNA molecule (see Anderson et al. 1981). The sequence from the bone was compared to those of 1,075 individuals from modern Pacific Island and Asian populations generated for other studies (Lum 1998, Lum et al.

Table 3. Skeletal elements and traits of the Kwajalein burial.

Skeletal Element and Trait	Left	Right
Clavicle		
Costo-clavicular sulcus	absent	absent
Supra-clavicular foramen	absent	absent
Scapula		
Humeral facet	-	present
Unfused acromial epiphysis	-	absent
Suprascapular border	-	absent
Shape of acromion	rectangle	retangle
Shape of vertebral border	-	-
Shape of inferior angle	V	V
Humerus		
Supratrochlear region	absent	absent
Septal aperture	absent	absent
Ulna		
Shape of trochlear notch	island	island
Innominate		
Accessory innominate and sacral facets	-	-
Acetabulum	-	-
Preauricular sulcus	absent	absent
Undeveloped acetabulum	-	-
Parturition pit	-	-
Femur		
Fossa of Allen	absent	absent
Fovea capitis	oval	oval
Femoral shaft bowing	-	slight
Anterior neck torsion	-	10–15
Third trochanter	absent	absent
Patella		
Vastus facet	absent	absent
Vastus notch	absent	absent
Patellar spurs	present	present
Tibia		
Tibia bowing	slight	-
Antero-distal squatting facet	present	-
Talus		
Talar extension	medial	medial
Talar squatting facet	medial	medial
Calcaneus		
Calcaneus facet	-	-
Peroneal tubercle	-	-

1994, Lum et al. 1998). The only sequences identical to the Kwajalein sequence are from the Austronesian-speaking Urak Lawoi living among islands off the coast of Thailand. There are two other sequences found within many geographically Micronesian populations that are only one (MCR1) or two (MCR2) bases different from the Kwajalein sequence (Fig. 8). The frequencies of these two related sequences within 11 geographically Micronesian populations and the Urak Lawoi are shown in Table 9. The frequencies of Lineage Group I (Lum et al.

Table 4. Observations of vertebrae from the Kwajalein burial.

Vertebra	Observation
Atlas vertebra (C1)	
Foramen transversarium	-
R:L foramen	-
Bridges to superior articular facet	-
Incomplete costal bar	-
Posterior spina bifida	no
Superior facet	constricted r and l
Axis vertebra (C2)	
Foramen transversarium	-
R:L foramen	r < l
Spinous process	parallel
Spina bifida	no
C3	
Foramen transversarium	-
R:L foramen	-
Spinous process	divergent
Spina bifida	no
C4	
Foramen transversarium	single, r and l
R:L foramen	r = l
Spinous process	divergent
Spina bifida	no
C5	
Foramen transversarium	-
R:L foramen	-
Spinous process	divergent
Spina bifida	no
C6	
Foramen transversarium	spur on l
R:L foramen	-
Spinous process	single
Spina bifida	incipient
C7	
Foramen transversarium	-
R:L foramen	-
Spinous process	single
Spina bifida	no

1994; Sykes et al. 1995) within each of these populations are also included in Table 9 for comparison.

Discussion

Figure 8 shows the Kwajalein sequence and two closely related sequences (MCR1 and MCR2) currently found within many Micronesian populations. Recent analyses of mtDNA sequence variation in large pedigrees (Howell et al. 1996, Parsons et al. 1997) have shown that mutations can occur much more rapidly than previously estimated from phylogenetic studies (Sherry et al. 1994).

Table 5. Observations on thorasic and lumbar vertebrae.

Vertebra	Laminal spurring	Spina bifida
T 1	no	no
T 2	yes	no
T 3	yes	no
T 4	yes	no
T 5	yes	no
T 6	yes	no
T 7	yes	no
T 8	yes	no
T 9	-	-
T 10	yes	no
T 11	yes	no
T 12	yes	no
L 1	no	no
L 2	no	no
L 3	no	no
L 4	no	no
L 5	no	no

It may be that these conflicting results reflect the mutation and the fixation rate of substitutions respectively. If so, the fixation rate may approach the mutation rate in small populations like the ones potentially colonizing islands. Thus the substitutions distinguishing the bone sample from MCR1 and MCR2 may have evolved in a relatively short amount of time. A similar amount of genetic diversity has been observed in Lineage Group I (Lum et al. 1994, Sykes et al. 1995). This group of related mtDNA sequences is characterized by the Region V deletion and accounts for the majority of nearly all modern Micronesian (Table 9) and Polynesian populations (Hertzberg et al. 1989, Lum et al. 1994, Lum & Cann 1998, Redd et al. 1995, Sykes et al. 1995). Lineage Group I contains a number of sequences that differ by one or two transition substitutions, similar to the divergence seen among the Kwajalein sequence, MCR1, and MCR2.

The sequence identical to the bone sample and MCR1 are both found within the Urak Lawoi at high frequencies (Table 9). Since the Urak Lawoi are "Sea Nomads," living much of the year on boats, it is possible that their lifestyle and their genetic sequences reflect retentions from an ancestral Southeast Asian population that contributed to the colonization of Micronesia (see Diamond 1988).

Table 9 lists the frequencies of MCR1, MCR2, and Lineage Group I within 11 geographically Micronesian populations. Inferences based upon a single sample are obviously highly speculative, but it is interesting to note that MCR1 is the numerically dominant lineage of the Mariana Islands. Previously we have argued, based upon genetic data (Lum & Cann 1998, Lum et al. 1998), that the Mariana Islands were settled independently from the rest of Micronesia. If the mtDNA profile within the Marshall Islands was constant throughout the past, then the *a priori* expectation based upon the modern population is a 94% chance of a given burial

Table 6. Measurements of Kwajalein burial human remains*.

Element and Measurements	Left	Right
Clavicle		
Maximum length	137.0	139.0
Sagittal diameter midshaft	11.0	10.5
Vertical diameter midshaft	15.0	14.5
Circumference at midshaft	31.0	30.0
Humerus		
Maximum length	303.0	300.0
Maximum head diameter	54.0	53.5
Minimum head diameter	44.0	44.5
Epicondylar breadth	63.0	61.0
Midshaft circumference	61.0	60.0
Maximum diameter at midshaft	24.5	22.5
Minimum diameter at midshaft	17.5	19.0
Radius		
Maximum length	-	-
Radial head diameter	24.5	-
Sagittal diameter of midshaft	-	-
Transverse diameter of midshaft	-	-
Ulna		
Maximum length	265.0	-
Dorso-volar diameter (maximum)	17.0	-
Transverse diameter	13.0	-
Physiological length	240.0	-
Minimum circumference	15.0	-
Femur		
Maximum length	432.0	-
Bicondylar length	427.0	-
Epicondylar breadth	82.0	-
Maximum head diameter	45.0	-
Subtrochanteric antero-posterior diameter	-	26.0
Subtrochanteric transverse diameter	31.0	-
Midshaft antero-posterior diameter	28.5	-
Midshaft transverse diameter	27.0	-
Circumference at midshaft	82.0	-
Tibia		
Maximum length	-	360.0
Anatomical length	-	350.0
Maximum epiphyseal breadth - proximal	-	74.0
Maximum epiphyseal breadth - distal	-	50.0
Maximum diameter at nutrient foramen	-	39.5
Transverse diameter at nutrient foramen	-	24.0
Midshaft diameter - antero-posterior	-	36.0
Midshaft diameter - transverse	-	20.0
Circumference at midshaft	-	83.5
Patella		
Height	-	45.0
Width	-	45.0
Thickness	-	22.0
Talus		
Maximum length 58.0	58.0	58.0
Maximum breadth 46.0	46.0	46.0

* = all measurements in mm.

Table 7. Mandibular measurements of the Kwajalein burial.

Measurement*	mm
Mandibular length	105.0
Inferior mandibular length	84.5
Alveolar length	50.0
Bicondylar width	123.5
Bicoronoid breadth	98.0
Bigonial breadth	98.0
Bicanine external breadth	36.0
Bimolar-1 external breadth	59.0
Bimolar-3 external breadth	69.0
Symphseal height	30.0
Mental foramen height	27.5
Canine height	26.5
Molar height	25.5
Symphseal breadth	13.5
Mental foramen breadth	14.0
Canine breadth	13.0
Molar breadth	16.5
Ramus height	55.5
Ramus breadth	39.0
Mandibular notch breadth	36.0
Condyle length	22.0
Condyle breadth	8.0
P3 - M1 length	17.0
M1 - M2 length	25.0
M1 - M3 length	33.5
Mandibular indicies	
Mandibular	85.0
Gonio-condylar	79.4
Ramus	70.3
Robusticity	50.9

* All measurements taken from left side.

belonging to Lineage Group I (Table 9). The Kwajalein sequence does not belong to Lineage Group I, thus it raises the possibility that lineages similar to MCR1 may have been more prevalent in other parts of Micronesia in the past. This would suggest a recent, post-settlement expansion of Lineage Group I sequences within Micronesia similar to the one suggested to have occurred in Western Polynesia by Hagelberg & Clegg (1993). Genetic analyses of prehistoric material from additional individuals and locations are required to assess these speculations.

Summary and Conclusions

The single human burial from Kwajalein Atoll, while a small sample, does provide the only directly radiocarbon-dated interment for the Marshall Islands and demonstrates the importance of well-documented human remains for addressing issues of prehistoric Micronesian settlement and human biology. We

Table 8. Measurements of Kwajalein burial teeth*.

Tooth	Mesial-buccal	Distal-lingual
Maxillary		
1 (R M3)	-	-
2 (R M2)	11.5	11.0
3 (R M1)	-	-
4 (R P4)	7.5	8.0
5 (R P3)	-	-
6 (R C)	8.0	8.5
7 (R I2)	7.5	7.0
8 (R I1)	-	-
9 (L I1)	8.5	7.5
10 (L I2)	7.5	6.5
11 (L C)	8.0	8.5
12 (L P3)	-	-
13 (L P4)	7.5	8.5
14 (L M1)	-	-
15 (L M2)	11.0	10.5
16 (L M3)	-	-
Mandibular		
17 (R M3)	-	-
18 (L M2)	-	-
19 (L M1)	11.5	10.5
20 (L P4)	7.5	8.5
21 (L P3)	-	-
22 (L C)	7.5	8.0
23 (L I2)	6.0	5.5
24 (L I1)	5.5	6.0
25 (R I1)	5.5	6.0
26 (R I2)	6.0	5.5
27 (R C)	7.5	8.0
28 (R P3)	-	-
29 (R P4)	7.5	8.5
30 (R M1)	11.5	10.5
31 (R M2)	-	-
32 (R M3)	-	-

* = all measurements in mm.

summarize here some issues of greater importance by placing the burial within a wider content.

Of the 151 shell ornaments associated with the Kwajalein burial, most were *Spondylus* disks that may have been worn as a necklace; the diameter of three *Conus* rings suggest they were worn on the upper arms and possibly within distended ear lobes; the polished *Pinctada* valve may have been a breast plate. The relatively high status of the burial is suggested by the rarity of substantial *Spondylus* valves (the best raw material for making sizeable red disks), large number of the disks associated with the interment, and the taphonomic evidence suggesting long-term curation of these ornaments. Large *Spondylus* disks may be a late prehistoric ornament type as identified in other parts of Micronesia (Butler &

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                                                   16160
Kwajalein  TATTGTACGG TACCATAAAT ACTTGACCAC CTGTAGTACA
MCR1       .......... .......... .......... ..........
MCR2       .......... .......... .......... ..........

                                                   16200
Kwajalein  TAAAAATCCA ATCCACATCA AAACCCCCTC CCCATGCTTA
MCR1       ......c... .......... .......... ..........
MCR2       ......c... .......... .......... ..........

                                                   16240
Kwajalein  CAAGCAAGTA CAGCAATCAA CCTTCAACTA TCACACATCA
MCR1       .......... .......... .......... ..........
MCR2       .......... .......... .......... ..........

                                                   16280
Kwajalein  ACTGCAACTC CAAAGCCACC CCTCACCCAC TAGGATACCA
MCR1       .......... .......... .......... ..........
MCR2       .......... .......... .......... ..........

                                              16315
Kwajalein  ACAAACCTAC CCACCCTTAA CAGTACATAG TACAT
MCR1       .......... .......... .......... .....
MCR2       .......... ....t..... .......... .....
```

Figure 8. MtDNA sequence of the Kwajalein sample. The sequence of the Kwajalein sample is given in the first line. Dots in the following sequences indicate identity and lower case letters indicate transition substitutions relative to the Kwajalein sequence.

Harris 1995, LeBar 1964); the Kwajalein radiocarbon age determination suggests this as well. The polished *Pinctada* valve, an ornament type more common in Polynesia, may signal some form of long-distance interaction between eastern Micronesia and island groups to the south—a position also taken by Bellwood from his review of the archaeological evidence for contact between Micronesia and Polynesia (1978:282). Certain plant names (e.g., for swamp taro, *Cyrtosperma*) are also shared between eastern Micronesia and the Polynesian atoll group of Tuvalu (Thaman 1987, Woodroffe 1985). And it is realistic to assume that the discrete geographical position of the “Micronesian-Polynesian” boundary we identify today may have been blurred in the distant past (Davidson 1988: 92). The 15th century date for the Kwajalein burial fits well within the period of long-distance interaction throughout Polynesia (Weisler 1997) and it would not be surprising that some manner of contact was made between the Marshalls and island groups farther afield. Ornaments obtained through long-distance exchange of the actual items, or ideas necessary to produce them, may have been funnelled through persons of higher status (Earle 1997). Especially on low coral atolls with limited biotic diversity and marginal terrestrial resources, maintaining ties with other vulnerable economies was essential for long-term survival (Weisler 1995). It seems reasonable, then, that the Kwajalein burial was an individual of relatively higher status.

Table 9. Frequencies of the Kwajalein bone sequence, two related sequences (MCR1 and MCR2), and Lineage Group I sequences (LG1) within present populations.

	n	Kwajalein	MCR1	MCR2	LG I
Urak Lawoi	9	33%	22%	0%	0%
Chuuk	33	0%	0%	15%	85%
Kapingamarangi	65	0%	0%	2%	98%
Kiribati	58	0%	0%	5%	75%
Kosrae	31	0%	3%	19%	78%
Nauru	28	0%	0%	7%	89%
Marshalls	31	0%	0%	3%	94%
Marianas	63	0%	67%	0%	10%
Outer Yap	138	0%	0%	0%	91%
Palau	142	0%	1%	0%	58%
Pohnpei	52	0%	8%	29%	58%
Yap Proper	69	0%	0%	0%	73%
Total	719				

The Kwajalein burial was an adult male, perhaps 30 to 40 years of age at time of death, 166.1 ± 3.27 cm (ca. 5 1/2 feet) in height, and in generally good health. His bones had well-marked muscle attachments, indicating that he led a strenuous life and the amount of dental decay and before-death tooth loss may be caused by dietary deficiencies like those observed in some ancient remains from Rota (Hanson 1990). A diet high in carbohydrate and/or sugar content is suggested by the lack of extensive tooth wear and presence of severe caries. If this individual was of relatively high status within the Kwajalein community, it may be that dietary deficiencies were a fact of atoll life in late prehistory. This may have been occasioned by denser human populations, lower productivity of garden soils, and a general diminution of marine shellfish and fish resources during late prehistory. Access to adequate nutrition may have been relegated to a select elite few.

The Kwajalein mtDNA sequence raises the possibility that lineages similar to that common in the Mariana Islands (MCR1) were more widespread in other parts of Micronesia in the past. This is intriguing since, based on the most widely accepted dating evidence for the Marshalls, the Marianas may have been settled up to 1,500 years earlier. This leaves open the possibility that the post-settlement history of the Marianas may have involved small groups venturing east to colonize or mix with existing populations in the eastern Carolines. The present mtDNA patterns may reflect a recent expansion of Lineage Group I sequences via interaction among Micronesian populations south of the Mariana Islands. Thus we concur with others that there may have been large-scale movement between islands following colonization (Rainbird 1994:300) and the timing and direction of these encounters await more detailed studies of artifacts, human biology, and mtDNA sequences from well-dated contexts. We have added here one small contribution to that goal as well as demonstrating the vital importance of human remains and associated grave goods for understanding Marshallese prehistory.

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