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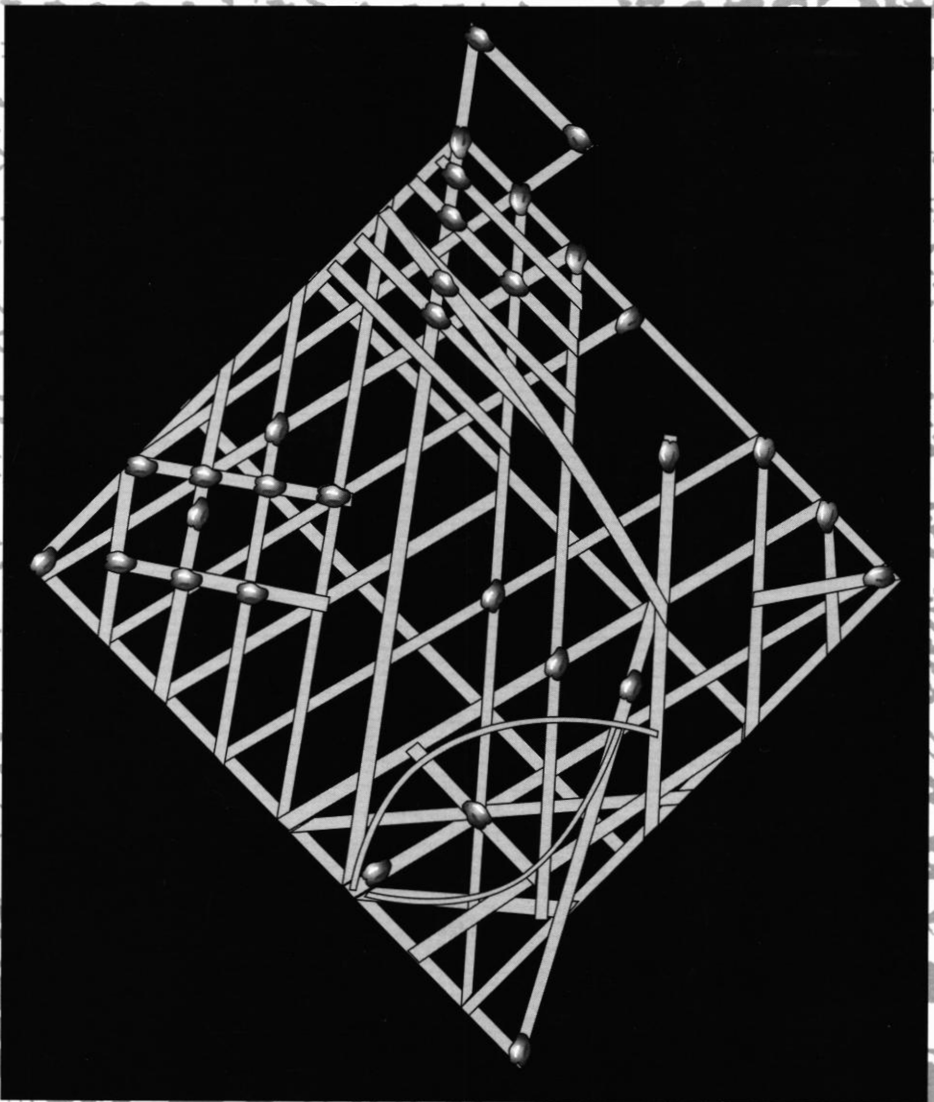

PREHISTORIC LONG-DISTANCE INTERACTION IN OCEANIA: AN INTERDISCIPLINARY APPROACH

Edited by Marshall I. Weisler

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NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION MONOGRAPH

PREHISTORIC LONG-DISTANCE INTERACTION AT THE MARGINS OF OCEANIA

Marshall I. Weisler

Oceania was the stage for the greatest maritime migration in human history with colonists visiting - if not settling - virtually every landfall across 10,000 km of sea during a few centuries of exploration. While early scholars such as Sharp (1956) viewed the sea as a barrier breached only by accidental or drift voyages, the prehistoric settlement of the Pacific is now known to have been purposeful, directed and motivated by a range of factors (Finney 1977; Irwin 1989, 1992; Levison *et al.* 1973). Indeed, the reasons for settling new islands could have entailed the continued quest for discovering new lands with abundant and pristine resources (Anderson 1996), banishment of those defeated in battle or to demonstrate prowess in navigational skills. The Lapita settlement of Remote Oceania was instantaneous in terms of the limits of radiometric dating (Kirch and Hunt 1988), yet there is some debate as to whether migration slowed - if not temporarily stopped - after entry into West Polynesia. This so-called 'pause' is not consistent with the rapidity of Lapita settlement of Remote Oceania (Irwin 1981) and awaits better archaeological documentation from island groups such as the Cooks and Societies.

Another interesting facet in the prehistoric colonisation of the Pacific is the settlement of the ecologically-marginal landfalls that lie scattered across the whole of Polynesia (see Terrell 1986:91). Limited in terms of sustainable resources, these islands are typified by their isolation, poor soils, unpredictable or limited rainfall and a low diversity of terrestrial fauna. That these islands were inhabited after colonisation and harvesting of their abundant pristine resources is a remarkable achievement of Polynesian settlement strategies.

It is perhaps within these marginal areas of the eastern Pacific that the process of Oceanic colonisation was pushed to its limits. How increasingly isolated communities survived after initially reaping the benefits of untapped resources is best understood in a regional context where one or more small marginal communities were connected to high volcanic islands with larger human populations and more diverse resources (see Cherry 1985 for the Mediterranean). Inter-island communication was the vital link for providing marriage partners and replenishing cultigens and industrial stone within an interaction sphere of resource-poor islands that depended on larger islands with diverse resources. To better understand the process of sustaining resource-restricted islands at the margins of Oceania, I examine the prehistoric interaction sphere in southeast Polynesia that consisted of the high volcanic islands of Mangareva and the diminutive and widely-spaced islands of the Pitcairn group. A review of the archaeological context and geological background for understanding provenance studies in the region is undertaken to document the transfer of volcanic artefacts, pearl-shell, cultigens and commensal animals during at least four centuries. Reasons for the cessation of inter-island voyaging are also explored.

ARCHAEOLOGICAL CONTEXT

Southeast Polynesia (defined here as Mangareva and the Pitcairn group) consists of 30 islands with a cluster of about 25 surrounding Mangareva lagoon, Temoe 40 km to the east, and the four dispersed Pitcairn islands, 400 to 1000 km distant. Most islands in the region are small, being remnants of steep volcanic Pleistocene volcanoes, but also include the low coral atolls of Oeno and Ducie, and Henderson - an uplifted limestone (*makatea*) island. The salient details of the geology are presented in another section; here, I summarise the archaeology of the main islands, consisting of *ca* 335 m^2 of archaeologically-excavated material; further details are provided elsewhere (Weisler 1993a:190-214; 1994, 1995, 1996a, b).

Mangareva

Main islands. Because early Polynesian archaeology and material culture studies were conducted by ethnographers such as Peter Buck, his colleague Kenneth Emory, and others such as Ernest Beaglehole and Ralph Linton, surveys emphasized stratified sites that contained large quantities of highly-stylistic artefacts - analysis of which could be used to demonstrate cultural affinities and, therefore, migratory routes, a key issue of this time (Howard 1967). Consequently, when archaeological research began in Mangareva in 1934, Emory surveyed the main islands for major architectural and rockshelter-cave sites (Emory 1939). His extensive - rather than intensive - survey, recorded numerous architectural features and complexes and the locations of several villages (1939). Excavations were conducted at a rockshelter and coastal midden at Agakauitai, but were not reported in much detail (Emory 1939:30). Although Emory's survey was clearly biased towards architectural features and rockshelter-cave sites, he did provide the first observations of settlement patterns documenting that villages were situated along the narrow coastal flats and consist of house pavements (*paepae*), alignments, gardening features such as terraces and pits, and perhaps a religious structure or *marae*.

Roger Green conducted the only stratigraphic excavations in Mangareva. In 1959, six sites were excavated on the islands of Mangareva, Aukena and Kamaka - the latter being a very small islet where the most intensive work was completed (Green 1960). Two partial prehistoric villages were mapped at Akamaru as well as individual sites on several islands. A total of *ca* 75 m^2 was excavated and four carbon age determinations established human occupation by the 12th century A.D. Green recovered a large collection of mostly pearl-shell jabbing and rotating fishhooks (Green ms; see also Sinoto 1983:61), trapezoidal and quadrangular basalt adzes (both late prehistoric forms), coral and echinoid spine abraders, human burials and faunal material.

Up until 1990, no large coastal midden sites had been recorded in Mangareva due to an emphasis on architectural features (Emory 1939) and on excavation of rockshelter sites (Green 1960). Weisler surveyed the islands of Mangareva, Taravai, Agakauitai, Kamaka, Aukena, Akamaru, Tenoko and some of the *motu* between Vaiatekeue and Totegegie on the northeast margin of the group, recording midden sites on all the major islands as well as the diminutive off-shore island of Tenoko (Weisler 1996a). Associated with a large coastal midden on the south shore of Taravai were numerous *paepae*, a ponded spring-fed irrigated terrace system (Weisler 1996a:74), dense midden concentrations exposed in the wave-cut face and at least one human burial. A thorough search of the main islands failed to locate any sources of stone-tool quality fine-grained basalt, but medium to relatively fine-grained rock was found exposed at several dykes on few islands.

Temoe atoll. In a short overnight visit to Temoe atoll - some 40 km southeast of Mangareva - Emory recorded several *marae*, *paepae* and burial features along the *motu* of the east and north sides of the island. Additionally, in two weeks in May, 1992, Weisler mapped more than 200 features (*marae*, a coastal midden, *paepae*, burial complexes, and trails) adding many new sites to the island's inventory. Unlike the main Mangareva group, Temoe's settlement pattern is virtually intact. House pavements are located along the lagoon shore and stepping-stone trails connect these habitations to small family(?) *marae* on the ocean side.

Summary. A total of 75 m^2 have been excavated in Mangareva and several dozen architectural features, and more than a score of coastal middens have been located. Although the earliest dates for human occupation are during the 12th century A.D., earlier sites must surely exist, especially since islands to the east were known to have been settled several hundred years earlier and materials in them were imported from Mangareva. Settlement patterns are similar to those recorded for other island groups in eastern Polynesia where architectural features are clustered in villages based, in part, on the constraints of topographic settings. In Mangareva, major settlements and few irrigated agricultural sites are located along the narrow coastal margins, with dryland cultivation features immediately inland on the upland slopes. Fishponds or weirs, located on the adjacent coasts, were often associated with these habitations (Fig. 9.1).

Pitcairn Islands

Ducie atoll. Archaeological investigations have been conducted on three of the four widely-spaced Pitcairn islands. Nearly 1000 km from Mangareva at the extreme eastern limit of the region, Ducie atoll - barely 2 km across and containing only two species of plants - has not been visited by an archaeologist. Because the island is barely 2 m above sea level, lacks fresh water and is extremely isolated, it is unlikely that it could have supported more than causal visitors. The presence of the Pacific rat (*Rattus rattus*) and humanly-transported land snail, *Pacificella variabilis* (Preece 1995:304-305), suggest that the island was, most likely, visited by Polynesians.

Oeno atoll. Closest to Mangareva at the opposite end of the Pitcairn group, Oeno atoll - roughly the size of Ducie - has been surveyed for archaeological sites. Only a small cairn constructed of coral cobbles and possibly of prehistoric age was located near the high water mark. Excavation revealed that it was constructed on the natural ground surface and no cultural material was recovered. It is probably due to the dynamic nature of the Oeno shoreline that evidence of intermittent coastal occupation would have been removed by storms and other erosional processes. However, a basalt

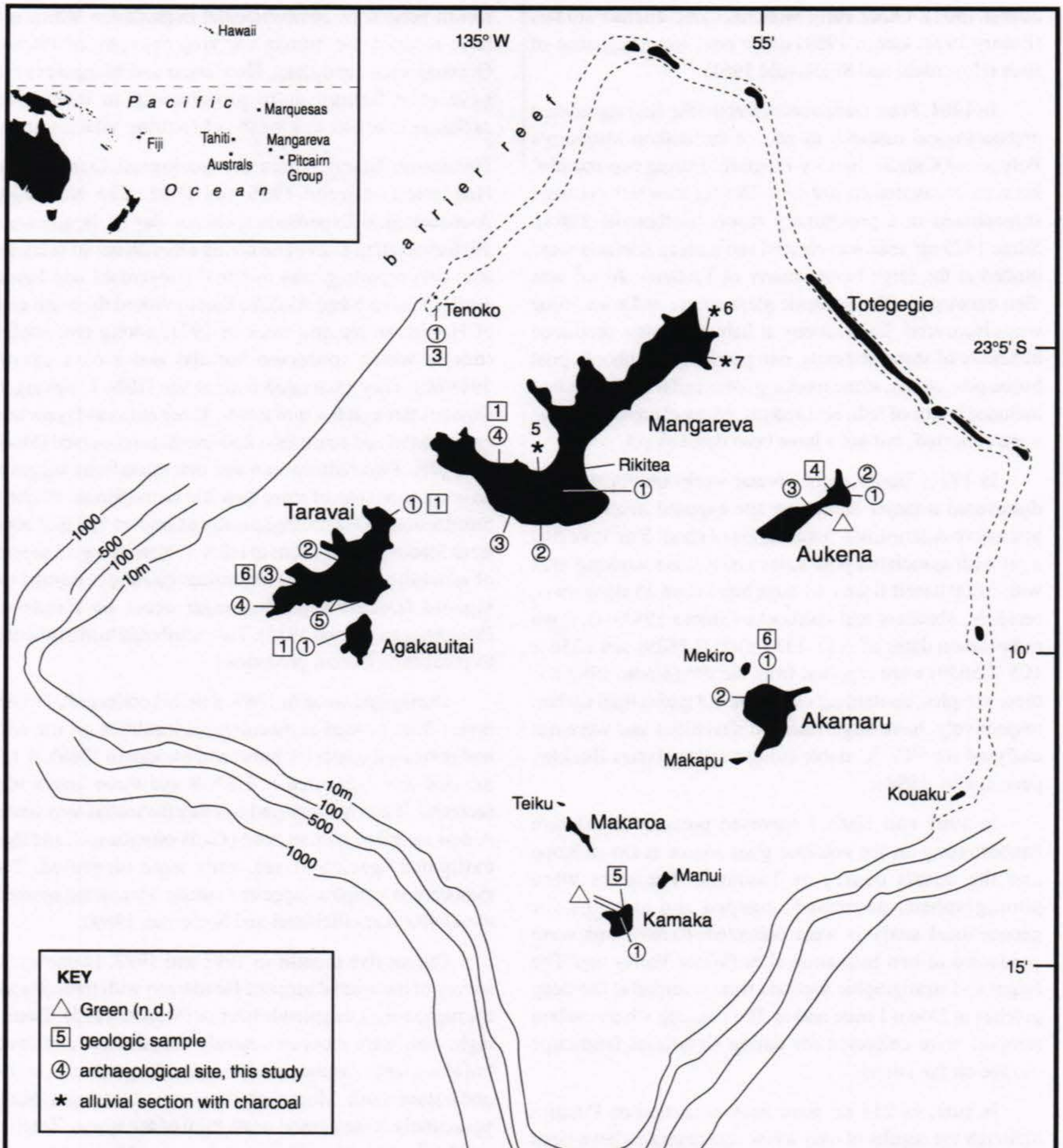

FIGURE 9.1. The main islands of Mangareva showing major archaeological sites and locations of rock samples collected for geochemical study (after Weisler 1996a:67).

adze found by one of the crew of the *Wildwave* wrecked in 1858 off Oeno, was thought by Emory to be of Mangarevan style (1928:132). This may not, however, mean it comes from Mangareva, and Pitcairn is an equal possibility.

Pitcairn island. The most famous island in the group is undoubtedly Pitcairn, and archaeological remains were reported by several early visitors who were largely interested in petroglyphs (Lavachery 1936; Routledge 1919; also

Seurat 1904). Other early work included artefact studies (Emory 1928; Green 1959) and a brief reconnaissance of sites (Heyerdahl and Skjølsvold 1961).

In 1964, Peter Gathercole directed the first significant archaeological research as part of the Bishop Museum's Polynesian Culture History Program. During two months, his crew excavated *ca* 209 m^2 at 10 sites, of which six were summarised in a preliminary report (Gathercole 1964). Some 1475 m^2 area was cleared and surface artefacts were plotted at the large basalt quarry of Tautama; 20 m^2 was then excavated. The volcanic glass source at Down Rope was discovered. Excavations at habitation sites produced hundreds of stone artefacts, one pearl-shell fishhook, post holes, pits, ovens, stone working areas and food refuse that included bones of fish, bird and pig. Many charcoal samples were collected, but none have been dated as yet.

In 1971, Sinoto spent several weeks on Pitcairn and discovered a major habitation site exposed in a road cut just above Adamstown. Excavation of about 5 m^2 revealed a pit with associated post holes and a stone working area with 5,000 basalt flakes, 61 adze blanks and 25 stone awls, scrapers, abraders and fishhooks (Sinoto 1983:61). Two radiocarbon dates of A.D. 1335 ±105 (I-5629) and 1350 ± 105 (I-5630) were reported from the site (Sinoto 1983:61; these samples, containing *ca* 0.7 and 0.8 grams final carbon respectively, have large standard deviations and were not analysed for $^{13}C/^{12}C$ stable isotope ratios (James Buckley pers. comm. 1994).

In 1991 and 1992, I surveyed portions of Pitcairn concentrating on the volcanic glass source at Down Rope and the basalt quarry at Tautama. The sites were photographed, described, mapped and samples for geochemical analysis were collected. Excavations were conducted at two habitation sites (Water Valley and The Edge) and stratigraphic sections were recorded at the deep gulches at Down Fence and at The Landing where carbon samples were collected for dating significant landscape change on the island.

In sum, *ca* 214 m^2 have been excavated on Pitcairn although the results of only a few square meters have been reported in any detail. Two radiocarbon samples - dating to the 14th century - suggest, as with Mangareva, that much of the early occupation awaits discovery. Prehistoric occupation of Pitcairn was intensive with major habitation areas at Adamstown and Tedside - major settlements located at opposite sides of the island (Fig. 9.2). The central plateau was undoubtedly the agriculturally-productive core of the island and significant landscape alteration has been recorded in the two main drainages where sterile sediments - more than a metre thick - overlie cultural deposits. These events record periods of environmental degradation which may have reduced the human carrying capacity of Pitcairn. Granting such conditions, Henderson and Mangareva may have once figured more prominently in inter-island exchange relations as a means of securing vital resources.

Henderson Island. Three archaeological teams visited Henderson between 1956 and 1992. The Norwegian Archaeological Expedition spent one day on Henderson in 1956 excavating a cave and noting a human burial in another site; data reporting was minimal (Heyerdahl and Ferdon 1961). Yosihiko and Akihiko Sinoto visited the north coast of Henderson for one week in 1971, noting five shelters (one of which contained burials) and a cave (Sinoto 1983:60). They excavated 6 m^2 at site HEN-1, sieving the deposits through 6.4 mm mesh. Three cultural layers were encountered and more than 250 artefacts recovered (Sinoto 1983:60). Two radiocarbon age determinations suggested an occupation span of more than 300 years (Sinoto 1983:61). Steadman and Olson subsequently examined 303 bird bones from Sinoto's excavations at HEN-1, identifying 12 species, of which the storm petrel (*Nesofregetta fuliginosa*) and two pigeons (*Ducula* spp.) no longer occur on Henderson (Steadman and Olson 1985). They attributed bird extinctions to prehistoric human predation.

During one week in 1987, Schubel collected 2795 bird bones from several archaeological localities on the north and northwest coasts (Schubel and Steadman 1989). A 1.25 m^2 unit was excavated at HEN-8 and three layers were recorded. It was not reported whether the matrix was sieved. A new record of ground dove (*Gallicolumba* sp.), and three extirpated species of sea birds were identified. Two radiocarbon samples suggested human occupation spanning about 400 years (Schubel and Steadman 1989).

During five months in 1991 and 1992, I conducted a survey of the coastal areas of Henderson with transects into the rugged and inhospitable interior (Weisler 1995). Twenty-eight sites were recorded, mostly rockshelters and caves, but also a large coastal midden, four relic gardening locales and a stone vault. Most such sites were coastal and located particularly at the coastal north third of the island. Totalling *ca* 42 m^2, excavations were conducted at 15 sites to sample the cultural deposits for artefacts, faunal material, radiocarbon and sediment samples. Twenty-three radiocarbon age determinations suggest earliest occupation at cal A.D. 898 to 942 (at 1 s, standard deviation) to the 17th century. The artefact sequence documented a period of imported materials from colonisation to *ca* A.D. 1450 with a significant change to artefacts manufactured from only locally available raw materials. Imported artefacts included fishhooks from Mangareva made of black-lipped pearl-shell (*Pinctada margaritifera*), basalt adze material and

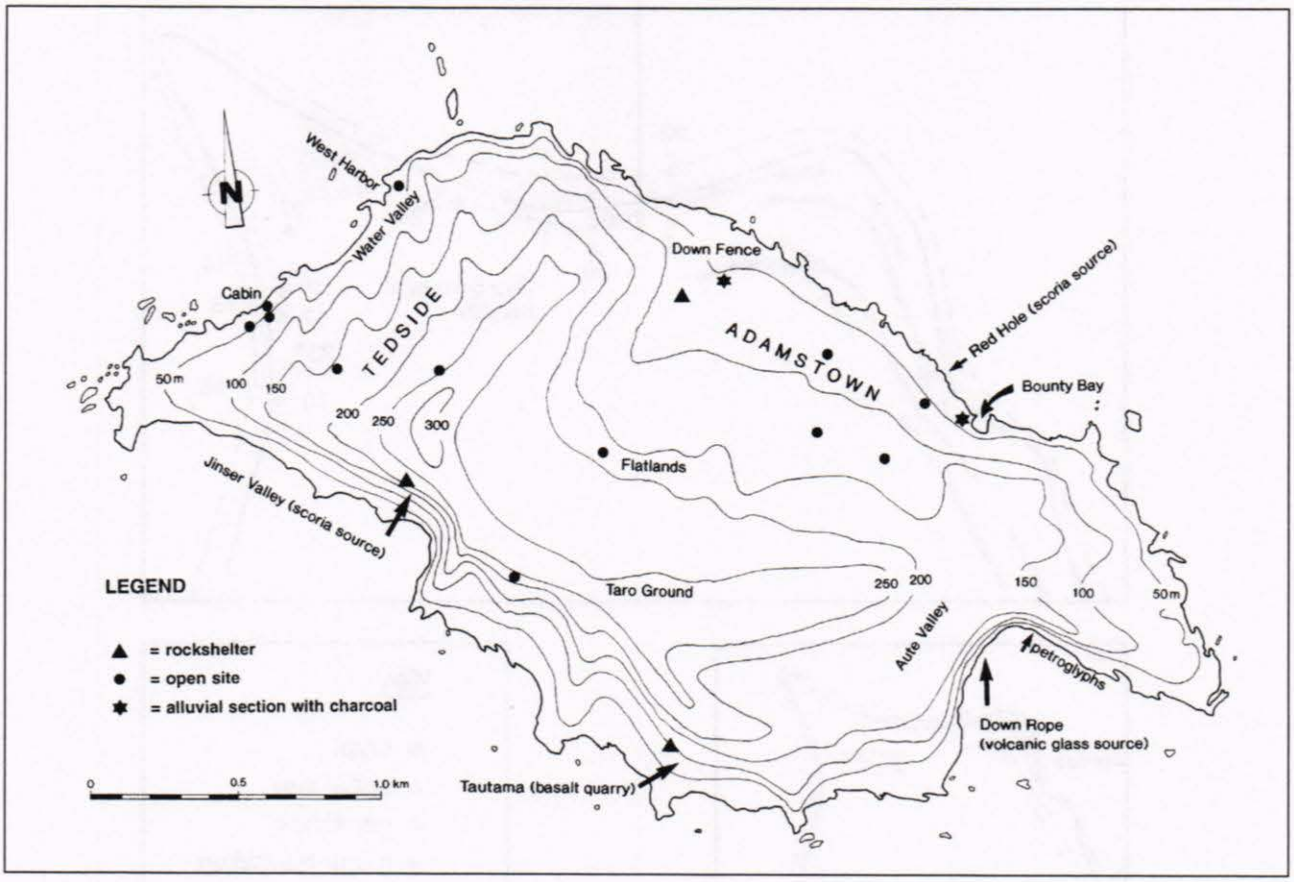

FIGURE 9.2. The late Pleistocene volcanic island of Pitcairn with prehistoric sites and archaeologically-documented sources of volcanic rocks that were important commodities in the southeast Polynesia interaction sphere (after Weisler 1995:384).

oven stones from Mangareva and Pitcairn, and volcanic glass from Pitcairn. After the cessation of inter-island communication, the artefact inventory consisted of *Tridacna* shell adzes, *Isognomon* pearl-shell fishhooks and a complete absence of volcanic oven stones which were replaced with limestone and reef rock. All bird extinctions took place during the time of inter-island voyaging (Wragg 1995; Wragg and Weisler 1994).

In sum, nearly 50 m^2 have been excavated on Henderson and 28 sites recorded. The major site classes consist of rockshelters and caves, a coastal midden, four gardening areas and a stone slab vault (Fig. 9.3). Faunal assemblages reflect the low species diversity for the area. *Turbo* (truban shell) was the dominant gastropod, most fish taxa are inshore species and all extinct bird taxa date to the period of inter-island communication; that is, prior to A.D. 1450.

Summary. The diminutive islands of the Pitcairn group provided prehistoric Polynesians with an enormous challenge - sustaining long-term habitation on resource-poor and isolated landfalls. At opposite margins of the group, Ducie and Oeno atolls could only have maintained small migrant groups which is suggested by the presence of only one small stone cairn. The same could be said for the *makatea* island of Henderson, with its poor soils, limited potable water, low species diversity and narrow reef margin. Pitcairn, therefore, stands out as the only inhabited island today. Yet, at least once in its recent history, the small population had reduced the island's resources to dangerously low levels requiring the evacuation of residents to Norfolk. This condition may have been repeated in prehistory. Thus, within this region, contact with Mangareva was vital for long-term survival.

SOUTHEAST POLYNESIA AS A PROVENANCE ENVIRONMENT

The notion of a 'provenance environment' derives from the need to couple geological knowledge with an archaeological problem orientation. For example, when

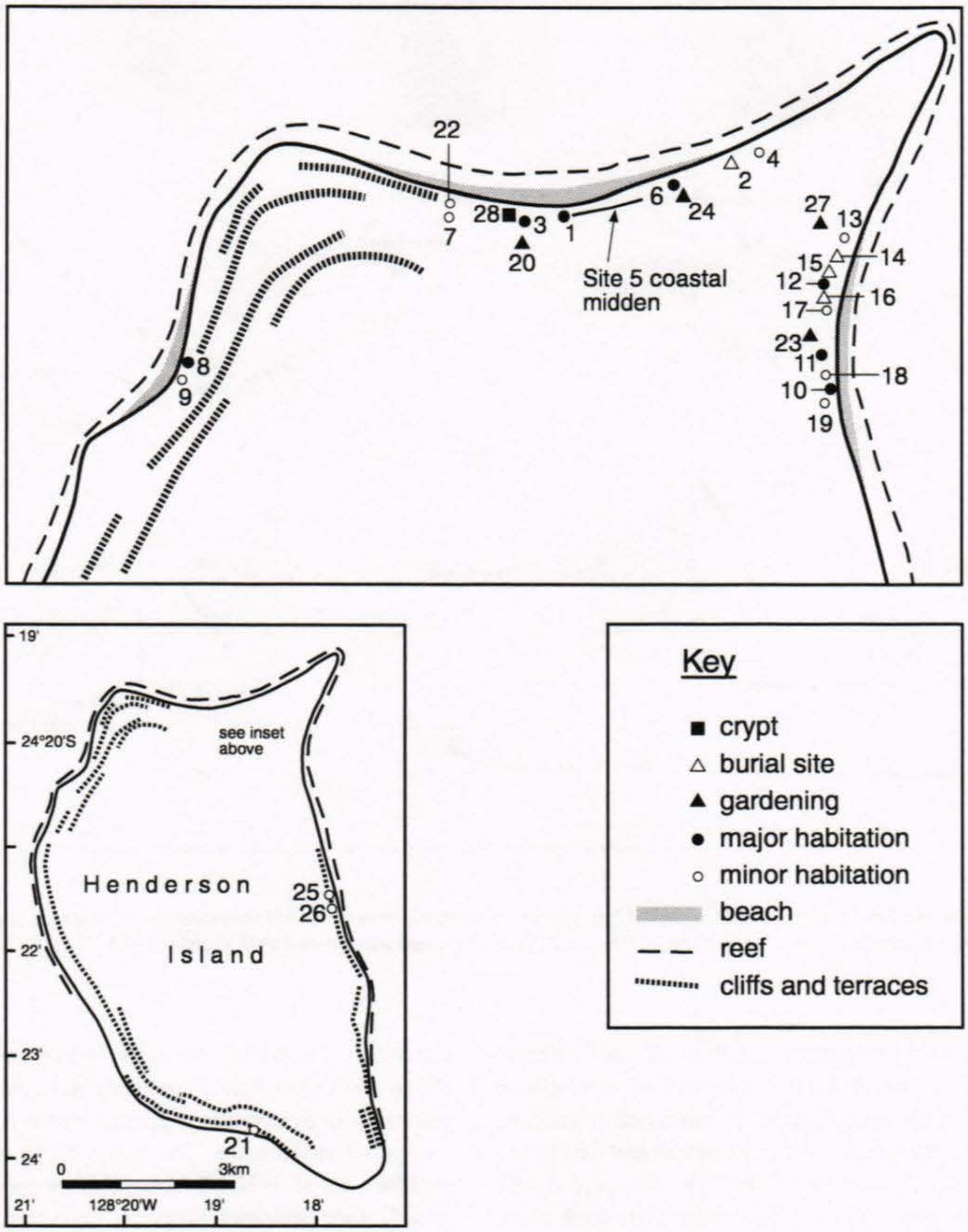

FIGURE 9.3. The uplifted limestone (*makatea*) island of Henderson showing the location and function of archaeological sites.

considering the temporal duration and spatial scale of prehistoric interaction in the Mangareva-Pitcairn group, it is unlikely that distant archipelagoes, such as Hawaii and the Society Islands, had any involvement with the southeast Polynesian interaction sphere. We know this from the archaeology and, consequently, we do not need to overly complicate the problem of assigning artefacts to source by including geological data from archipelagoes remote from the region of interest. As defined here, the Mangareva-Pitcairn interaction sphere is isolated from the nearest volcanic islands: the closest is Rapa, 1100 km southwest, Rapa Nui is *ca* 1600 km east, and one must pass through the low coral atolls of the Tuamotus, to get to the Societies, more than 1600 km to the northwest. Considering the abundant local resources of fine-grained basalt, volcanic glass and black-lipped pearl-shell, it is less likely that artefacts from distant archipelagoes would be identified in southeast Polynesia.

The islands of the Pitcairn group and Mangareva (Gambier Islands) are of Oceanic Island Basalt origin. The Pitcairn-Mangareva lineament is time-progressive with islands increasing in age toward the northwest (Duncan and McDougall 1976) which conforms to the 'hot-spot' hypothesis (Woodhead and McCulloch 1989) typical of other island chains such as the Australs, Marquesas and the Hawaiian Islands. Geologic studies in southeast Polynesia, especially during the past two decades, have added significantly to our understanding of the age, petrology, geochemistry and geomorphology of these islands (Brousse and Guille 1974; Brousse *et al.* 1974; Carter 1967; Duncan and McDougall 1976; Weisler 1996a; Woodhead and McCulloch 1989).

Fifteen major islands comprise this region of southeast Polynesia and vary from high volcanic islands (e.g., Mangareva and Pitcairn), to the raised limestone island of Henderson, to several low-lying atolls (e.g., Temoe and Oeno). The basalt foundation of limestone islands and atolls lie deeply submerged making these volcanic rocks inaccessible to prehistoric occupants. Consequently, all volcanic rocks found on these coralline islands are imported by humans or, in rare instances, small volcanic pebbles are deposited from seasonally migrating birds that regurgitate gizzard stones. Drift trees are also known to carry rocks imbedded in their roots, although this is less common for the isolated islands of east Polynesia than in the western Pacific. The distribution of alkalic and tholeiitic rocks throughout this region also has implications that aid provenance studies and is described later. I now summarise the geological characteristics of the islands of southeast Polynesia and highlight the unique aspects of this region as a provenance environment.

Mangareva

Situated at the northwest extent of the study area, the 11 largest islands of Mangareva range in size from 0.065 km^2 (Makapu) to 14 km^2 (Mangareva) and have a combined total area of *ca* 25 km^2 (Fig. 9.1). Except for Temoe atoll which lies 40 km southeast from the main group, the islands surround a central lagoon 25 km from north to south. A barrier reef with several atolls fronts the northern extent, while the southern periphery is open to the dominant southeast swells. Mangareva and Taravai (5.3 km^2) comprise nearly 80% of the total land area, with the remaining islands averaging less than 1 km^2. The volcanic islands are characteristically steep and rugged with denuded slopes that descend to narrow coastal plains. Small intermittent streams are found on Mangareva and Taravai where the largest embayments and widest coastal flats are present and irrigation was possible.

The volcanic rocks of Mangareva comprise the major volcano-building stages and minor occurrences of the late stage alkalic eruptives. Brousse and Guille (1974:174-177) divide these oceanic basalts into tholeiites which comprise the vast majority of rocks and include altered tholeiites (those with H_2O content >2.75%), alkali basalts and oceanites. The alkalic rocks, generally fine-grained and unweathered, are an important group since they are most often the source of adze material throughout Polynesia (see Weisler 1993b: Fig. 3). They are extremely limited in occurrence and have been documented at only a few locations in Mangareva. Alkalic flows are located on the upper south slopes above Roi on Mangareva at 441 and 170 m, and near the northeast point of the island (Brousse and Guille 1974:161,218). These rocks are also known from the southwest coast of Makapu and an unspecified locale on the slopes of Akamaru (Brousse and Guille 1974:Table 21, sample 34C).

The tholeiitic and oceanitic rocks are generally medium to coarse-grained and were used prehistorically for building habitation structures and agricultural features; cobbles were used as oven stones, and manufactured into stone tools such as canoe anchors and food pounders. Buck lamented the lack of information about quarries in Mangareva (1938:275). Laval, however, recorded six varieties of rock used for oven stones and to manufacture stone tools (quoted in Buck 1938:260). One class of rock, ostensibly used for oven stones, was reddish, vesicular and resistant to fire and termed *tataravera-kakaraea, tataravera-one, tataravera-oaga'* and *poatu-tumu* (*po'atu-tuma*). The other major class was for manufacturing stone tools and was black with a fine close grain, unsuitable for oven stones because it exploded in the fire. These varieties were termed *po'atu-maori, kina, iva, koma, ke'o-tamata* and *ke'o-taki*. Buck reports that Laval states definitely that the *koma* was for axe manufacture and *ke'o* for adzes and files (Buck 1938:260).

My own archaeological and geological survey of the main Mangareva islands failed to locate any sources of fine-grained basalt with evidence of debitage (Weisler 1996a) and neither Emory or Green found such. Several adzes examined from private collections on Mangareva were very fine-grained and exhibited flow banding thus are similar in appearance to basalt from Tautama, Pitcairn, although geochemical studies are necessary to determine this with more certainty. Relatively fine-grained rocks are found at dyke exposures on many of the islands, and Green suggests that rocks used in construction of a mission road on Aukena "are of a rock identical with that used in the manufacture of many of the adzes in our collection" (1960:24), but he did not locate their source. I suggest, however, that any very fine-grained basalt artefacts recovered from Mangareva archaeological sites are more likely imports. Additionally, only very thin selvages of volcanic glass - measuring only a few millimetres in width - were observed at a few dykes and their manufacture into flake tools is also unlikely. The island group could serve as a source of vesicular basalt oven stones (of tholeiitic composition) and fine to medium-grained rock for grinding and pounding stones, simple flake tools and inferior grade adzes. In contrast, high-quality adze rock and volcanic glass (ignimbrite) is more likely imported.

Pitcairn Islands

The Pitcairn group consists of four islands: Pitcairn ($4.5\ km^2$), a Pleistocene volcanic island; the elevated limestone island of Henderson ($36\ km^2$); and the two atolls of Oeno and Ducie. The islands are perhaps the most isolated group in the world, situated 1600 km west of Rapa Nui and approximately 400 km east of Mangareva. Only Pitcairn Island is volcanic and is discussed here in detail.

Rising at least 3.5 km from the sea floor, the lavas comprising Pitcairn Island are divided into four volcanic formations ranging in age from 0.45 to 0.95 Ma (million years) (Carter 1967:11-28; Woodhead and McCulloch 1989:258-259). In contrast to the tholeiitic (and rare alkalic) lavas of Mangareva, Pitcairn is composed solely of alkaline rocks, a major boon to regional provenance studies. That is, all artefacts of alkaline composition recovered from archaeological contexts on Henderson probably originated from Pitcairn sources.

The most important source of fine-grained rock is located on the south side of the island at Tautama (Carter 1967:36; Gathercole 1964; Fig. 9.2). Several flows of dark grey mugearite are exposed at the base of the cliff along a talus slope and within the gulch that flows to the beach. This area is the site of the largest known adze quarry in southeast Polynesia.

Water-rounded volcanic cobbles are found on all the coastlines, but are most accessible on the south side at Down Rope, along the shore at Tedside, and at The Landing near Bounty Bay on the east exposure (Fig. 9.2).

The greatest concentration of dykes, often a source of fine-grained rock, is intrusive into the Tedside volcanics and may have been a minor source of stone-tool quality rock. Thin volcanic glass selvages were seen on few of the rocks forming a talus below the dykes and above the boulder beach.

The largest volcanic glass (actually, ignimbrite) source in southeast Polynesia (not including the obsidian deposits at Rapa Nui), is located below the tuff cliffs on the west side of Down Rope. The raw material occurs as subrounded cobbles and is found at archaeological sites all over Pitcairn. It was exported to Henderson and perhaps elsewhere in the region.

Summary of regional geology

As a provenance environment, the islands of Mangareva and the Pitcairn group have several unique geochemical characteristics that facilitate the identification of lithic material imported to habitation sites within the region. (1) Since no tholeiitic rocks occur on Pitcairn, any artefacts found within the region which consist of a low alkaline chemical composition, with depleted mid-Z elements such as Rb (rubidium), Sr (strontium), Zr (zirconium), Nb (niobium) and Y (yttrium) and low MnO (manganese-oxide), probably originated from Mangareva. Such artefacts may include ground and flaked stone artefacts as well as oven stones. (2) Artefacts of alkaline composition with enriched mid-Z elements are from the largest source of fine-grained rock known in the region at Tautama, Pitcairn; use of this quarry has been documented archaeologically. (3) Alkalic rocks are known from a few isolated exposures on three islands in the Mangareva group but, based on present evidence, they were not used prehistorically - or, at least not extensively - and may not have been suitable for stone-tool manufacture. (4) Only a limited and poor quality volcanic glass is known from Mangareva, while the largest source of this material outside of the rhyolitic obsidian of Rapa Nui is at Pitcairn.

The natural and archaeological distribution of black-lipped pearl-shell in southeast Polynesia

Black-lipped pearl-shell inhabits lagoons that are protected from strong currents. They grow attached to coral heads and pinnacles to depths in excess of 30 m (Coeroli 1985:372). Buck reports that pearl oysters - found in abundance in the shallows of the lagoon at Mangareva - were used for food and that the shells were used to manufacture fishhooks and other tools (1938:5). Considering the large area of the Mangareva lagoon - *ca* 25 km from north to south - and the relatively low human population of the archipelago, stocks of pearl-shell were essentially inexhaustible during prehistory. It is interesting to note that during the height of the pearl-shell fishery in the late 19th century, about 45,500 kg of pearl-shell were harvested annually (Coeroli 1985:372). Heavy exploitation reduced this number to *ca* 4,500 kg about 75 years later. Regardless of the accuracy of these figures in relation to changing international markets of supply and demand, Mangareva prehistorically had virtually an inexhaustable stock of black-lipped pearl-shell. This is reflected in the archaeological record where pearl-shell is present throughout the known 700 year sequence (Green 1960). The occurrence of pearl-shell throughout the prehistoric occupation of archaeological sites adjacent to plentiful stocks of black-lipped pearl-shell has also been demonstrated for Tongareva, an atoll in the northern Cook Islands (Bellwood 1978).

Eastward in the Pitcairn group which lies at the periphery of the Indo-West Pacific biotic province (Kay 1984), the presence of pearl-shell is greatly restricted due to unfavorable habitats and probably to an increase in water temperature. Black-lipped pearl-shell was introduced to Oeno atoll, the western most island in the group, during the turn of the century (Jacob Warren pers. comm. 1991). Although the lagoon of Oeno appears to be conducive for pearl-shell growth, this taxon was not reported from any biological surveys to date.

In their mollusc and fish survey of Ducie atoll conducted over three days in 1971, Rehder and Randall reported that "The most striking thing about the lagoon is the paucity of life" (1975:14). Only one large specimen of black-lipped pearl-shell was collected at about 4 to 7 m depth in the northern end of the lagoon (Rehder and Randall 1975:34). Pearl-shell was obviously not plentiful and the extreme isolation of Ducie from the rest of the Pitcairn Islands that were inhabited prehistorically suggests Ducie as being an unlikely source of pearl-shell. The lack of recorded pearl-shell stocks at Oeno, and only rare occurrences of the taxon at Ducie, may be due to the lower lagoon water temperatures. Water temperature near the middle of Ducie lagoon near the surface and at 16 m was 26.5° C and is some 3° cooler than lagoon waters situated closer to the equator (Rehder and Randall 1975:14). The colder temperatures influence the production of spat and consequently limited the reproductive capabilities of the stocks (Coeroli *et al.* 1984).

While relatively lower water temperatures may be a significant factor limiting the growth and reproduction of black-lipped pearl-shell at Oeno and Ducie atolls which have protected lagoons, Pitcairn is surrounded by exposed rocky coastlines and turbulent waters; the dominant shellfish include turban, *Nerita* (nerites) and Patellidae (limpets) which reflect this environmental setting. At Henderson, only one small valve of the black-lipped pearl-shell was found despite the presence of a scientific team for 15 months (Benton and Spencer 1995; Weisler *et al.* 1991).

In summary, black-lipped pearl-shell is quite limited in its natural occurrence within the Pitcairn Islands, yet it is found in archaeological deposits on both Pitcairn and Henderson. Probably owing to the acidic lateritic soils of Pitcairn, only one pearl-shell fishhook was recovered from extensive excavations conducted by Gathercole (1964). The Norwegian Expedition purchased a pearl-shell scraper and two rectangular pieces (maximum dimensions of 7 and 8 cm) from Tom Christian for $US 5.00 that he collected from the area above Sailor's Hide, west of Adamstown (Tom Christian pers. comm. 1992; Heyerdahl and Skjølsvold 1961:156, plate 1e). Excavations by the author at Water Valley in 1991 confirmed that only the enamel portions of scarid and shark teeth were preserved at some sites. At Henderson, however, black-lipped pearl-shell was recovered from nearly all sites that had cultural deposits dated prior to A.D. 1450. Pieces up to 15 cm long from large valves were found, as well as cut and worked shell, and finished hooks.

A survey of the natural distribution of black-lipped pearl-shell in southeast Polynesia, revealed that Mangareva had the largest stocks of this important raw material. Rare occurrences of pearl-shell have been documented at Ducie and Henderson which may suggest its limited presence on Oeno atoll located nearest to Mangareva and the source of natural stocks. The archaeological distribution of pearl-shell documents its importation to Pitcairn and, especially Henderson. The abundance of this material at Henderson may be due to the excellent conditions for preservation in contrast to Pitcairn's acidic soil conditions. This inference could be tested with further archaeological investigations on Pitcairn.

Summary

The uneven distribution of important raw materials within southeast Polynesia suggests that reciprocal exchange relationships were important for distributing resources. Examining the natural distribution of basalt (both fine-grained rock for stone tool manufacture and vesicular material used for oven stones), volcanic glass and pearl-shell permits the delineation of possible interaction spheres between islands in Mangareva and the Pitcairn group. Since fine-grained basalt was an important material for the manufacture of adzes and other tools, and since it is localized to Pitcairn - where the largest source of this material is found within the region of southeast Polynesia - it is likely that it was exchanged to other islands in the region. Indeed, Pitcairn stone may be present in private collections of adzes examined recently on Mangareva. With a similar naturally-restricted occurrence, volcanic glass from Pitcairn may also be present in Mangareva. A geological survey of all the major volcanic islands of Mangareva failed to locate a single useable source of this siliceous rock.

Volcanic oven stones, ideally cobbled-sized vesicular rocks, are far superior to limestone, beachrock or *Tridacna* valves that were commonly used for oven stones on coral atolls such as Temoe, or Henderson, a raised limestone island. Indeed, Buck mentions that Tukairoa left Mangareva for Hao atoll in the Tuamotus with a "cargo of (basalt) rocks" (1938:46). It is likely that imported oven stones, that originated on Pitcairn or Mangareva may be found in archaeological deposits on non-volcanic islands in the region. The distribution of pearl-shell suggests further that this material would be an important component of exchange within southeast Polynesia. Since Mangareva is unquestionably the largest source of this commodity, its distribution in archaeological sites in the Pitcairn group is likely.

METHODS

General field methods and sampling strategy

Conducting scientific research on a remote and uninhabited landfall presented unique logistical problems not the least of which were arranging private yacht transportation and acquiring dependable potable water on an ecologically-marginal island. The nearest medical doctor was in Tahiti, more than 1600 km away, and a trip of several days under the best circumstances; consequently, it was not possible to bring a large archaeological crew. Besides the universal limiting factors of time and money, isolation and logistics were very real considerations in formulating a research design. Extensive area excavations and routine fine sieving, that are very labour intensive, are clearly of importance in many circumstances, but were simply not realistic procedures here. I decided, then, to at least test excavate all major habitations to understand the cultural-historical sequence for each site. The goals were to determine *trends* and events in the archaeological record at as many sites as time permitted. Was the distribution and relative abundance of imported artefacts the same across all sites? Did bird extinctions coincide temorally across most sites? Were the sites all abandoned at the same time? These are questions that could be addressed with small excavated samples from rockshelter and cave sites ranging from 37 to 225 m^2 in area. The focus of this paper examines the trends in material imported to Henderson from its neighbour islands.

Some 42 m^2 were excavated at 10 rockshelter and cave sites from all areas of the coastline, including a large coastal midden and several gardening locales (Fig. 9.3). All cultural deposits were excavated stratigraphically with thicker layers divided into 5 cm arbitrary levels for finer vertical control. Most layers were dry-sieved through 6.4 mm mesh (some especially black midden layers were wet-sieved), while samples passed through 3.2 mm and 1.6 mm mesh were used to monitor what was lost through larger sieves (Weisler 1995:385). Radiocarbon samples were collected from the top and bottom cultural layers of all sites as well as from combustion features. Of prime importance was datable material associated with imports which could chronologically delimit the period of inter-island interaction. I describe below the analytical methods used for determining the provenance of volcanic artefacts, pearl-shell and plant and faunal remains imported to Henderson Island during more than four centuries.

Volcanic artefact analysis

Because analytical techniques vary from inexpensive to very costly, from non-destructive to destructive which utilize samples of varying sizes, and require a broad range of knowledge and skills, it is important to consider the overall goals of a sourcing program. Must we know the exact geologic source of an artefact down to the specific quarry, flow or dyke? Is it sufficient to identify the island group or volcano from where the artefact originated? Or, is it simply enough to demonstrate that the artefact is exotic to the locale where it was found? Careful consideration of these questions will dictate the techniques required to solve specific archaeological problems. In this study, it was sufficient to know that the artefacts originated from a particular island group (e.g., Mangareva), a specific fine-grained basalt source (Tautama, Pitcairn), a particular dyke (at Tedside, Pitcairn) or volcanic glass deposit (Down Rope, Pitcairn). Techniques that were first non-destructive and, second, the least expensive, were emphasized. Destructive and more expensive techniques were used to evaluate source characterizations and artefact assignments made with less powerful techniques or, in the example of vesicular basalt oven stones, the technique was used that was most appropriate for the rock type.

Sourcing by macroscopic attributes. Assigning fine-grained basalt artefacts to source by the macroscopic characteristic of colour has proven unreliable. Colour is not only a reflection of the physical properties of the rock, but is more likely a result of surface weathering of the artefact or staining by midden sediments. In some well-defined geological contexts, flow banding - alternating light and dark bands which can often be seen in hand specimens - may suggest a specific source. Currently in East Polynesia, this can be done reliably only within the West Moloka'i volcanics (Hawaiian Islands) and when differentiating Tautama, Pitcairn source material from rocks on Mangareva; this latter region, however, requires relatively fresh, unweathered rocks to enable accurate source assignment and initial groupings should be tested with more powerful techniques.

As a sole technique, macroscopic observations are reliable only within explicitly defined contexts using volcanic glass. For example, the green obsidian from Mayor Island, New Zealand (Davidson 1972), the well-studied obsidian sources from northern California (Bettinger *et al.* 1984) and the volcanic glass from Pitcairn Island (Weisler and Clague 1997) all can be visually identified and artefacts assigned to source within acceptable limits. In New Zealand, artefact colour alone is not always reliable for accurately sourcing obsidian.

As detailed above, the Pitcairn ignimbrite at Down Rope is a unique volcanic glass not only within the Pitcairn group, but for the whole of Polynesia. To test the efficacy of visual sourcing the Down Rope ignimbrite, volcanic glass was selected from archaeological and geological sources from the closest islands to Pitcairn: Mangareva, the Marquesas and Rapa Nui, as well as material from Hawaii and Samoa. Although I detected some small visual differences between some non-Pitcairn volcanic glass, it was possible 100% of the time, to separate the Pitcairn ignimbrite. Even with pieces less than 3 mm in maximum length, the distinctive black to gray patches are clearly visible allowing accurate source assignment. I used energy-dispersive x-ray fluorescence to evaluate my source assignments of 14 artefacts macroscopically identified as Down Rope ignimbrite, with 14 sources of volcanic glass from throughout Polynesia. (Complete details of this analysis are presented in Weisler 1993a:216-217; 233-239.) In all cases, source assignment was correct.

Non-destructive energy-dispersive x-ray fluorescence (EDXRF). The EDXRF technique is fast and inexpensive and can be used with minor sample preparation. When used as a non-destructive technique, it produces geochemical results that are best considered as semi-quantitative data when used with basalt. The selection of artefacts for geochemical study was governed by minimum sample weight and size. The opening of the sample holder where the x-ray beam is directed to the specimen is 32 mm in diameter. Experience has shown that careful placement of the artefact or rock sample in the EDXRF instrument may accommodate samples up to 421 g and 136 mm long. Specimens as small as 10 mm can yield useful results. Many of the Henderson volcanic artefacts are very small (<2 g) and several specimens could not be analysed. As the results demonstrate, however, few geochemical groups were present in the Henderson assemblages and the small, unanalysed specimens probably reflect the overall geochemical groups of the analysed artefacts.

One hundred and eight artefacts were analysed by EDXRF and included five whole and fragmentary adzes, two adze preforms, one used flake, three cores, 18 polished basalt flakes, 65 unmodified basalt flakes and 14 volcanic glass flakes and cores (see Fig. 9.4 for examples of volcanic artefacts). All artefacts that fit the specifications of the EDXRF equipment were analysed. Not all volcanic glass was analysed because its source could be determined by macroscopic characteristics (as described above).

Wavelength-dispersive x-ray fluorescence analysis (WDXRF). Wavelength-dispersive x-ray fluorescence is the preferred technique when greater accuracy is required or if samples, such as oven stones, have an uneven specimen surface (or topography), vesicles, relatively large grain size and large phenocrysts that could over-represent certain oxides and elements thus biasing the average geochemical composition of the artefact when analysed by EDXRF. Sixteen fire-altered vesicular basalt oven stones were analysed, many of which were found in association with combustion features. Sample preparation, equipment and operating conditions are reported in detail elsewhere (Weisler 1993a:77-78).

Pb isotope analysis of fine-grained basalt. There are some areas in Polynesia where routine EDXRF or WDXRF cannot discriminate within source overlap and accurately assign artefacts to a source - at some geographic scale (see Chapter 10:Fig. 10.3). On present evidence, these regions are limited to Tutuila island, Samoa where there are several large and numerous small basalt sources (Chapter 5), and a few unspecified sources within the southern Cook Islands (Chapters 6 and 7). Source overlap and artefact assignment is a potential problem as variation in trace and major element abundances is largely controlled by near-surface magma-chamber processes which are generally similar between some oceanic islands. These issues are discussed further in Chapter 13 and current research by Weisler and Woodhead seek to resolve these problems with the highly accurate Pb isotope technique.

The Pb isotope technique was used here to evaluate the efficacy of EDXRF and WDXRF for source characterisation and artefact assignments and to analyse very small samples that could not be accurately analysed by EDXRF. The technique requires only 100 mg (milligrams) of sample material and is one of the least evasive of the destructive techniques that are routinely used in sourcing studies. The specific equipment and operating conditions used for this analysis are detailed in Weisler and Woodhead (1995:1883-1884). Of the six artefacts from Henderson Island analysed by the Pb isotope technique, two were vesicular basalt oven stones previously analysed by WDXRF, and of fine-grained basalt, three flakes and one core were analysed by EDXRF.

Summary of volcanic artefact analysis. Figure 9.5 illustrates the protocol for the analysis of volcanic artefacts from Henderson Island. At level 1, all volcanic artefacts are sorted

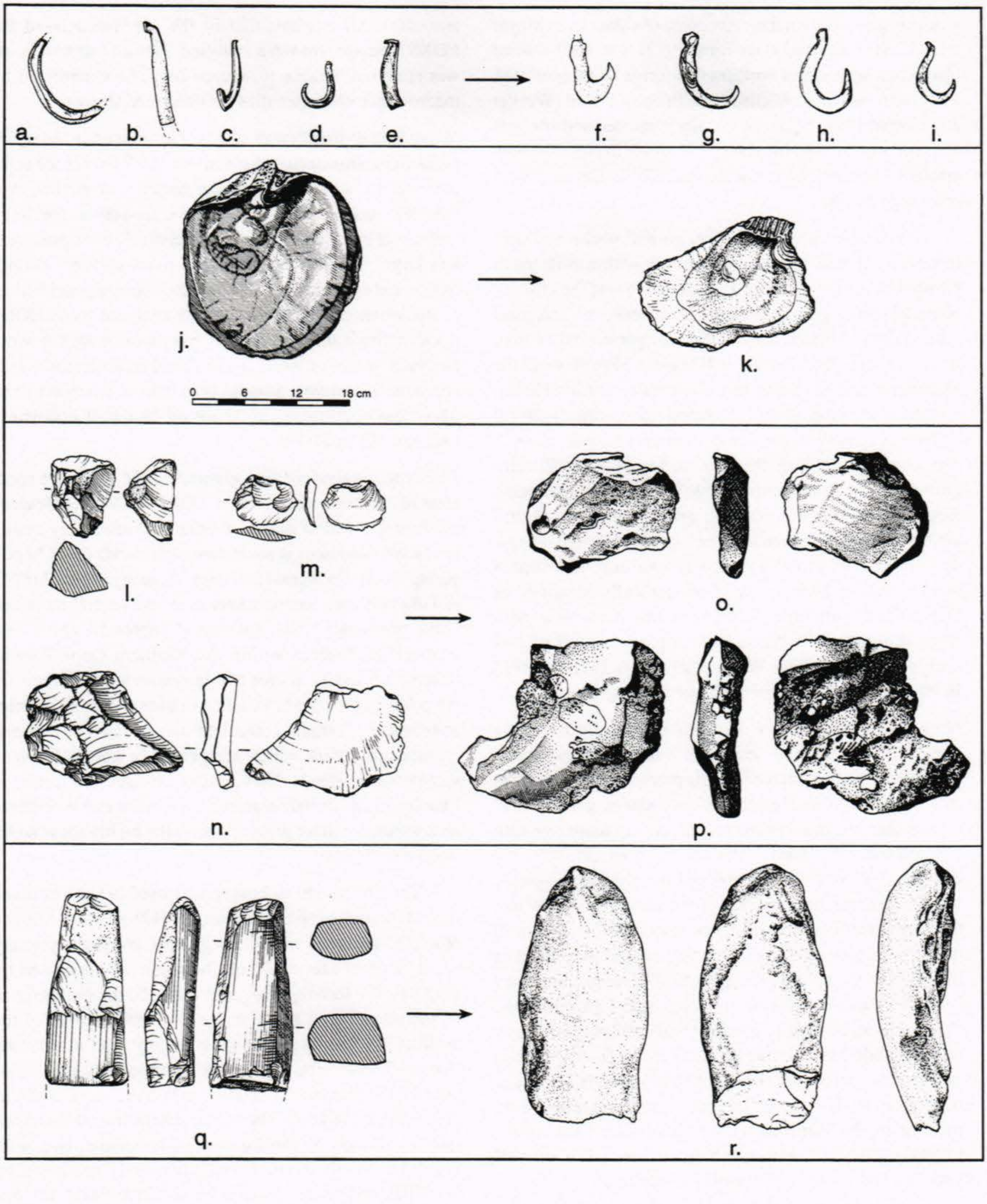

FIGURE 9.4. Examples of Henderson artefacts recovered from the period during voyaging (left column) and after inter-island contact (right column). Arrows show direction of artefact change. a - e, fishhooks of black-lipped pearl-shell (*Pinctada margaritifera*); f - i, *Isognomon* sp. fishhooks; note size differences between valves of the black-lipped pearl-shell (j) and the much smaller oyster, *Isognomon perna* (k); volcanic glass core (l) and flake (m), both from Pitcairn; n, Tautama, Pitcairn basalt flake awl; o, used *Tridacna* sp. flake; p, beachrock flake; q, adze of Tautama, Pitcairn basalt; and r, *Tridacna maxima* shell adze. All artefacts 50% of original except j.

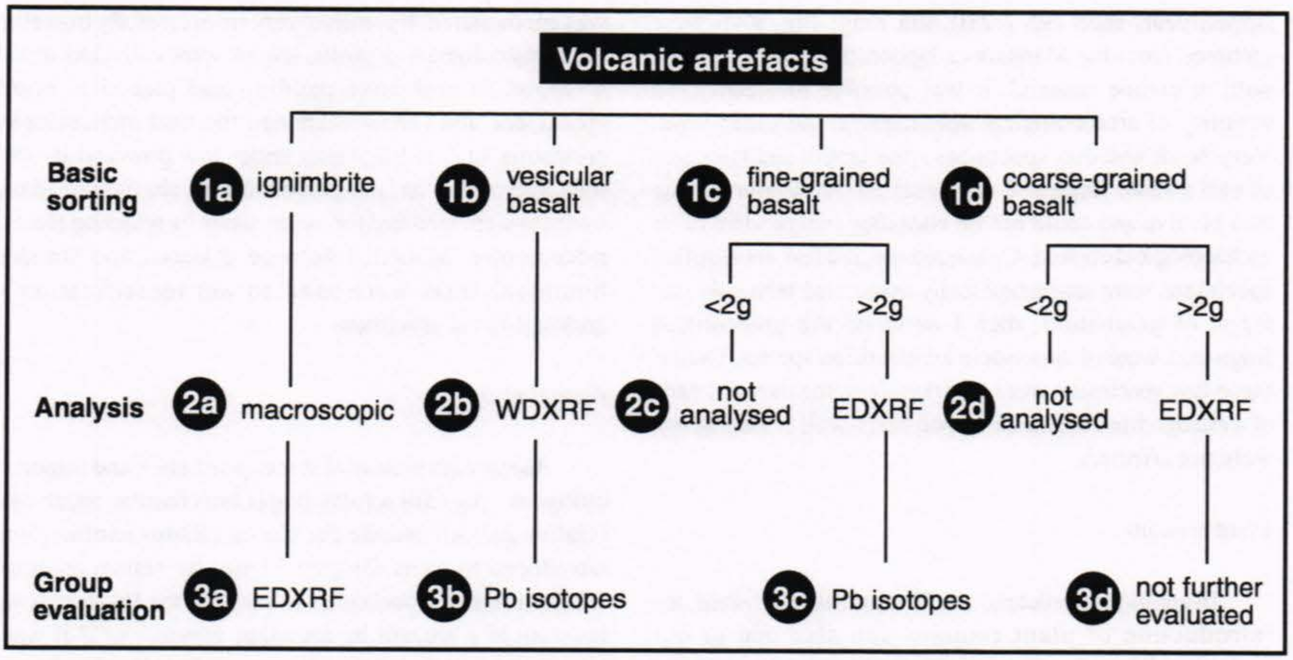

FIGURE 9.5. The protocol for sourcing volcanic artefacts recovered from habitation sites on Henderson Island.

into ignimbrite, vesicular basalt and fine- or coarse-grained basalt. The fine- and coarse-grained basalt are further sorted by specimens large enough for EDXRF analysis (> 2 g) and those less than 2 g that were not further analysed during this study. All ignimbrite artefacts were macroscopically examined for grey to black patches (level 2a) which determined that the source was Down Rope, Pitcairn Island. A sample of 14 artefacts, representing 10.6% of the total ignimbrite artefacts, were analysed further by EDXRF to evaluate source assignment (level 3a). All vesicular basalt artefacts (level 1b) exhibited evidence of heat alteration which suggested use as oven or cooking stones. Because of the presence of vesicles, large grain size and apparent phenocrysts, all of these artefacts were analysed by WDXRF (level 2b). To evaluate source assignment, 13.3% were analysed further by Pb isotopes (level 3b). In level 1, the non-vesicular basalt artefacts were further divided into fine- (1c) and coarse-grained (1d) material. Samples less than 2 grams were not analysed geochemically (2c and d), although techniques such as Pb isotopes and electron microprobe (Weisler and Clague 1997), and ion microprobe (Chapter 7) can accommodate much smaller samples. EDXRF was used at level 2c and d to analyse 108 basalt artefacts - those large enough to permit accurate geochemical results. Coarse-grained basalt was not analysed further, while the source assignment of 3.6% of the fine-grained basalt artefacts was evaluated by the Pb isotope technique (level 3c).

Black-lipped pearl-shell

The black-lipped pearl-shell bivalve has figured prominently in prehistoric inter-island interaction studies in the eastern Pacific. On the volcanic and makatea islands of the southern Cooks, fishhooks were manufactured from imported black-lipped pearl-shell in the earlier periods and replaced by local stocks of the turban gastropod during the cessation off-island communication (Kirch *et al.* 1995; Walter 1990; Chapter 6). In southeast Polynesia, fishhooks, and resulting manufacturing debris made from black-lipped pearl-shell (Fig. 9.4a-e), were replaced in later prehistory by the much smaller and locally available *Isognomon* pearl-shell bivalve, as the raw material (Weisler 1995; Fig. 9.4f-i). In areas where turban is common, it is possible to identify even small fragments of this raw material by its ribbed exterior sculpture. However, other criteria must be used for separating *Isognomon* from the black-lipped pearl-shell as they both have a smooth, flat nacreous interior.

In order to separate the different taxa found in archaeological deposits on Henderson, modern reference specimens were collected and compared for overall length and thickness, colour and topography of the interior nacreous surface and nature and colour of exterior surface or cortex. Twenty whole valves of *Isognomon perna* (maximum length ranged from 45 - 75 mm; Fig. 9.4k) were collected along the rocky embayment at Down Rope, Pitcairn Island, while 11 complete specimens of the black-lipped pearl-shell (95 - 210 mm long; Fig. 9.4j) were gathered from the Mangareva lagoon. From comparisons with reference material, it was possible to identify the majority of archaeological specimens at the genus level. Very small and thin specimens - the length and thickness of half a small fingernail - represented the interior portion of a bivalve and could not be classified independent of its archaeological context. Consequently, if a few unidentified specimens were stratigraphically associated with only one taxon of pearl-shell, then I assumed the unidentified fragments were of the associated identified species. Even if these few specimens were misidentified, the overall trends of a change from the black-lipped pearl-shell to *Isognomon* were not affected.

Plant remains

In addition to volcanic artefacts and all pearl-shell, the introduction of plant remains can also add to our understanding of prehistoric long-distance interaction. Carbonised wood is routinely recovered in Oceanic sites, while parenchyma (Hather 1991) and leaves have only recently been identified. While adding an important component to understanding prehistoric subsistence and economy, botanic remains provide another material class to monitor inter-island interaction. This is especially true for isolated, ecologically-marginal islands such as Henderson where nearly all the vital food plants were introduced as well as certain medicinal shrubs and some species used for firewood.

Wood charcoal was encountered in every excavation unit at all sites on Henderson. Charcoal pieces were hand-picked from sieves and bagged separately to avoid breakage during transit. The specimens were identified to nearest taxon from five $1m^2$ units from five sites on the west, north and east coasts. Assemblages were chosen from sites that represented: (1) contrasting environmental settings, for example, leeward verses windward sides of the island; (2) cultural layers representing occupation during and after the period of inter-island voyaging; and (3) different kinds of site use such as the intensively-occupied north coast verses the more isolated and presumably task specific west shore. Within excavation units, up to 30 specimens were randomly selected from each arbitrary level (or spit). These arbitrary levels were then correlated to stratigraphic layers. A total of 900 specimens were identified to genus by Jon Hather (University of London). Identifications were made by comparisons to modern reference specimens of all woody vegetation found on Henderson Island (Florence *et al.* 1995).

Organic preservation was excellent in the rain-protected rockshelters and caves where all the leaf material was encountered. Upon discovery from carefully trowelling the archaeological deposits, leaves were collected in situ, wrapped in protective padding and placed in sturdy containers. Jon Hather examined the total archaeological collection of leaf fragments under low powered incident light microscopy and portions of both the abaxial and adaxial surfaces were mounted for examination by scanning electron microscopy. Modern reference material and standard botanical texts were used to aid identification of archaeological specimens.

Faunal remains

Along with industrial stone, pearl-shell and important cultigens - pig (*Sus scrofa*), dog (*Canis familiaris*), chicken (*Gallus gallus*), and the Pacific rat (*Rattus exulans*) were introduced to many Oceanic islands by human colonists. While it remains unclear as to whether the Pacific rat was intentionally brought by founding groups - or if it was a stowaway - it is a proxy measure for charting human colonisation routes in the eastern Pacific (Matisoo-Smith 1994). Pig is an important food in secular and ritual contexts (Valeri 1985). By using comparative collections, all non-fish faunal material was identified by Alan Ziegler (private consultant, Honolulu, Hawaii) and Thomas Wake (University of California, Los Angeles) further identified the pig bones .

FOUR CENTURIES OF IMPORTATION

The geographically-marginal islands of Oceania, and especially those ecologically-depauperate landfalls at the edge of the Indo-West Pacific biotic province, now stand as mute testimony of the voyaging skills and ability of Polynesians to colonise isolated islands under extreme environmental conditions. As the changing frequency of imports demonstrates below, it was in large part by maintaining a 'lifeline' to Mangareva that the small populations on Henderson and Pitcairn survived for generations. However, extinction of the small community on Henderson followed inevitably after the breakdown in inter-island voyaging. Identifying the source and temporal span of materials imported to Henderson allows chronological placement of the extinction process. I present now the evidence for long-distance voyaging by examining a suite of imported materials: fine- and coarse-grained basalt, oven stones, pearl-shell, plant remains and faunal material.

Fine-grained basalt

In settlements far removed from high-quality stone, it seems likely that whole tools or preforms were imported and habitation sites should have evidence of tool breakage and reworking of these valuable artefacts. On Henderson, it is noteworthy that in addition to whole and fragmentary adzes, the amount and size of debitage, cores and hammerstones suggests that raw material was imported as well. All fine-grained basalt including polished basalt flakes (the evidence of adze reworking) and a used flake (Fig. 9.4n) were analysed geochemically. Polished basalt flakes may appear as early as A.D. 980 (Weisler 1995:Table 2, Beta-45603). Figure 9.6a is a bivariate plot of selected Henderson artefacts analysed by EDXRF (see also Table 9.1). After much experimentation, for this study ratios of Zr, Sr and Nb were found to be effective discriminators in most cases where oceanic island basalts are analysed. The results demonstrate that most of these formal artefacts originated from geochemical group A at the fine-grained basalt source at Tautama, Pitcairn. A single artefact, isolated from the main cluster, cannot be attributed to a specific source by this plot and will be analysed by other techniques in the future.

Extensive sampling of the Tautama source permitted delineation of three distinctive groups based in part by various levels of zirconium. These groups, labelled A, B and C, represent individual flows. Although raw material

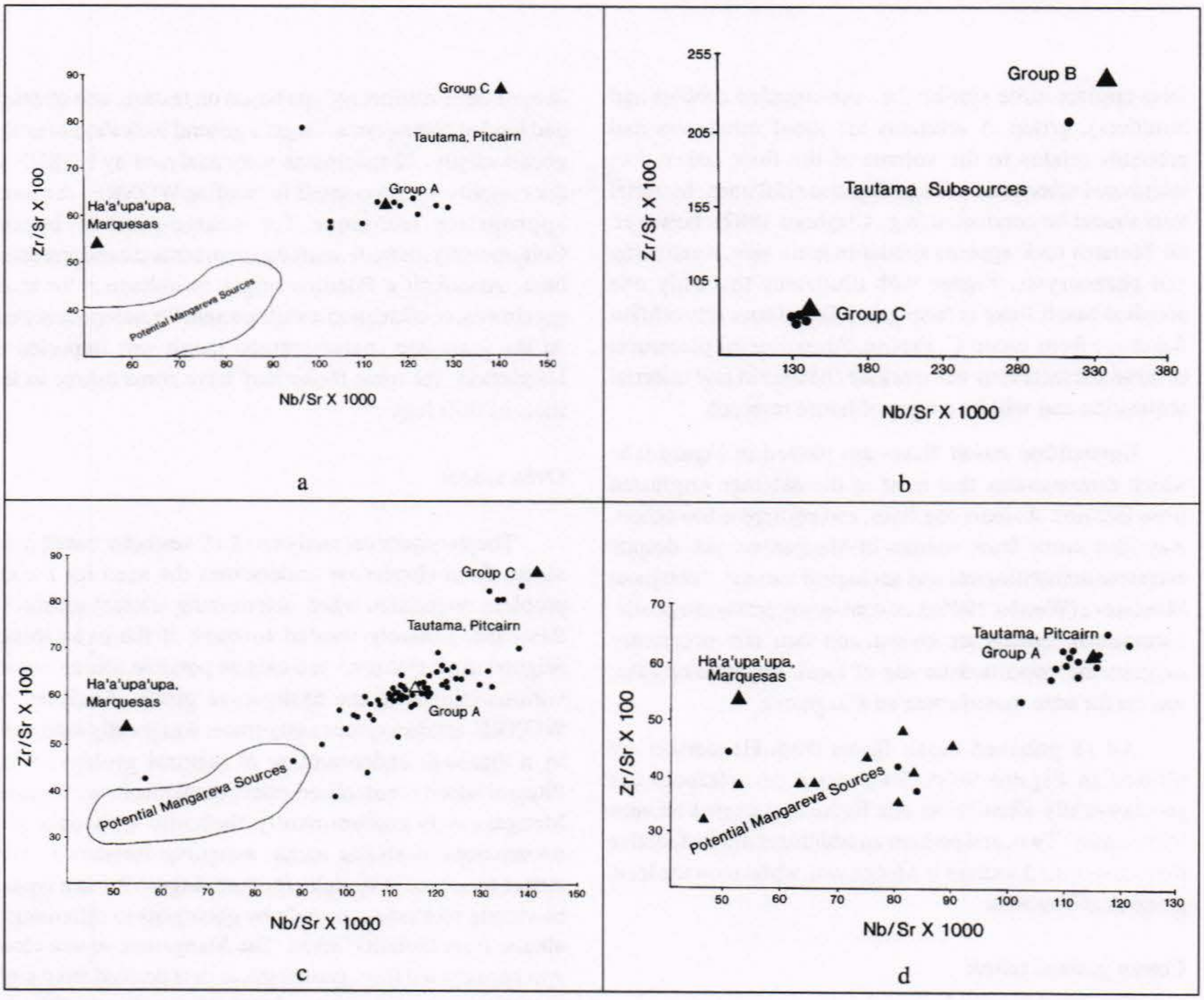

FIGURE 9.6. Bivariate plots of: a = selected Henderson artefacts (adzes, preforms, cores and a used flake); b = a fine-grained polished basalt flake and debitage from geochemical groups B and C from Tautama, Pitcairn; c = unmodified basalt flakes, mostly from group A, Tautama; and d = fine-grained polished basalt flakes (after Weisler 1993a:223, 225, 229 and 230).

Site	*Pinctada*		Volcanic glass		Basalt		Oven stones		All Imports	
	Count	Weight	Count	Weight	Count	Weight	Count	Weight	Count	Weight
1	34	19.4	12	18.4	95	178	0	0	143	219.6
3	16	8.2	66	23.3	66	376.6	2	192.8	252	700.2
5	94	90.6	43	45.6	87	1457.1	12	770.5	238	2365.3
6	39	15.9	5	7.9	14	95	0	0	73	134.1
7	0	0	0	0	1	9.7	0	0	16	45.6
8	0	0	0	0	0	0	0	0	28	47.4
10	7	1.8	6	14.8	18	313.5	0	0	61	412.7
11	0	0	0	0	2	6.9	0	0	8	20.3
12	1	0.4	0	0	1	64.6	0	0	9	80.8
21	0	0	0	0	0	0	0	0	1	0.8
22	0	0	0	0	0	0	1	16	1	16
Total	191	136	132	110	284	2501.4	15	979.3	622	3727

TABLE 9.1. Pearl-shell and volcanic imports to Henderson Island.

form appears quite similar (i.e., sub-rounded cobbles and boulders), group A artefacts are most numerous and probably relates to the volume of the flow rather than intentional selection by the prehistoric craftsmen. Material tests should be conducted (e.g., Cleghorn 1982); however, all Tautama rock appears similar in grain size, weathering and phenocrysts. Figure 9.6b illustrates that only one polished basalt flake is from group B and four unmodified flakes are from group C. Precise chronological placement of these artefacts may demonstrate changes in raw material acquisition and will be a topic of future research.

Unmodified basalt flakes are plotted in Figure 9.6c which demonstrates that most of the debitage originated from Pitcairn. At least one flake, and perhaps a few others, may have come from sources in Mangareva; yet, despite extensive archaeological and geological surveys throughout Mangareva (Weisler 1996a), no convincing archaeologically-documented sources are known, and their rare occurrence suggests the opportunistic use of local, but inferior lithic sources for adze manufacture on Mangareva.

All 18 polished basalt flakes from Henderson are plotted in Figure 9.6d. Two pairs of artefacts are geochemically identical in this figure and cannot be seen individually. Two, and perhaps an additional artefact, derive from unspecified sources in Mangareva, while most are from group A at Tautama.

Coarse-grained basalt

This class consists of abrading tools and unmodified tabular pieces of rock, the largest of which is about 93 mm long; most, however, are less than 40 mm in size. There are at least three distinct groups based on texture, and quantity and kind of phenocrysts. To get a general indication of group geochemistry, 22 specimens were analysed by EDXRF as the majority were too small for routine WDXRF - the more appropriate technique for coarse-grained basalt. Consequently, definite source assignments are not presented here. Although a Pitcairn origin is indicated for most specimens, confirmation awaits current Pb isotope analyses. At the least, the coarse-grained basalt was imported to Henderson, yet some rocks may have come ashore in the roots of drift logs.

Oven stones

The geochemical analysis of 16 vesicular basalt oven stones from Henderson underscores the need for a clear problem orientation when determining artefact source. In this case, I merely wanted to know if the oven stones originated on Pitcairn - the closest possible source - or on various islands in the Mangareva group. Analysed by WDXRF, artefact source assignment was greatly facilitated by a thorough understanding of regional geology. Since Pitcairn island is composed solely of alkalic lavas, whereas Mangareva is predominantly tholeiitic with only rare occurrences of alkalic rocks, assigning Henderson oven stones to source is straight-forward. Figure 9.7 is a typical bi-variate plot used routinely by geologists to differentiate alkalic from tholeiitic lavas. The Mangareva source cloud was constructed from geochemical data derived from eight potential sources on seven Mangarevan islands (Weisler 1996a:76-80), while the Pitcairn volcanic group was formulated from the published geological literature and new analyses of Tedside dyke rocks (Carter 1967; Woodhead

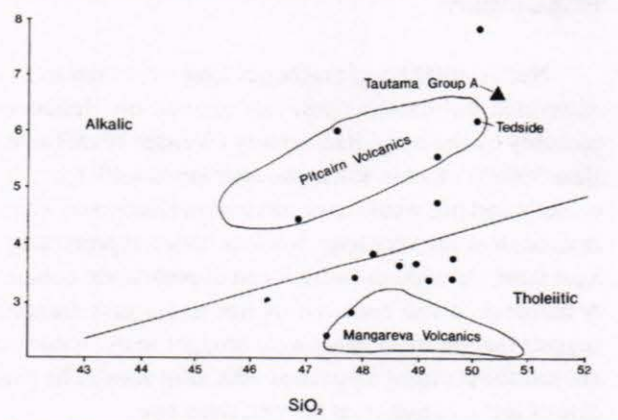

FIGURE 9.7. A typical silica-alkali plot illustrating that the origin of Henderson oven stones was Mangareva and Pitcairn (after Weisler 1995:401).

and McCulloch 1989). Surprisingly, just over half of the oven stones derive from unspecified sources on one or more islands in Mangareva. Of the artefacts sourced to Pitcairn, I can identify the exact dyke on the west coast at Tedside from where one oven stone originated; interestingly, Tedside is also near the best canoe landing on the island. Table 9.1 lists the distribution of oven stones by site.

Volcanic glass

Some 132 pieces of volcanic glass (total weigh = 110 g) were imported from Down Rope, Pitcairn beginning as early as A.D. 900 (Weisler 1995:Table 2, Beta-59005); this is about 400 years prior to the earliest dated habitation sites on Pitcairn. Ninety-five percent of the material was recovered from four north coast sites, with only six pieces found at an east coast locale. Artefacts included five cores (Fig. 9.4l), 126 unmodified flakes (Fig. 9.4m) and one used flake.

Black-lipped pearl-shell

Originating in the Mangarevan lagoon, 191 pieces of black-lipped pearl-shell weighing 136 g were imported to Henderson during the period of inter-island voyaging; most material has been dated to the 12th to 14th centuries. However, use of the black-lipped pearl-shell may have begun as early as A.D. 1000 (Weisler 1995:Table 2, Beta-59983). More than 98% of all pearl-shell was from sites along the north coast. The artefacts included finished whole and broken fishhooks (Fig. 9.4a-e), unfinished forms, tabs and manufacturing debris predominantly from the thinner margins of the valve, but several hinge fragments were also recovered (see Table 9.1). The latter suggest that whole valves were often imported and at least some fishhooks were manufactured on Henderson.

Plant remains

Of the eight taxa identified from contexts associated with the period of inter-island voyaging, at least six are clearly Polynesian introductions, one is of uncertain status but likely introduced, and another disperses naturally but is also humanly transported (Table 9.2). This latter taxon is the coconut (*Cocos nucifera*) and Pitcairners say that it was introduced within the last 100 years as no palms were then growing on Henderson. On present evidence it is not possible to determine if these eight taxa represent one or multiple introductions, especially on the ecologically-

Taxon	Status	Material Identified	Coast & sites where present	Dates of first introduction	^{14}C Lab No.
Aleurites	1	s	north: 3, 6, 7, 8; east: 10, 11, 12	1290-1440	45598
Barringtonia	1	w	east: 10	1330-1650	45600
Cocos	1,2	s,w,h	north: 1,5, 6, 7; east: 10	1000-1390	59983
Cordyline	1	l,w	north: 6, 7; east: 10, 11, 12	1330-1650	45600
Cyrtosperma	1	l	north: 6, 7	1330-1648	59009
Hernandia	?	w	east: 10	1330-1650	45600
Hibiscus	1	w	east: 10	1280-1430	45601
Musa	1	l	east: 11	1410-1660	45602

Status: 1 = Polynesian introduction; 2 = disperses naturally. Material: s = shell, l = leaf, w = wood, h = husk. Dates are from wood charcoal and presented as the calibrated ranges at 2 s after Stuiver and Reimer (1993). Lab numbers are preceeded by Beta.

TABLE 9.2. Prehistoric plant introductions to Henderson Island.

marginal island of Henderson where extinction of some taxa is likely, and re-introductions, if possible, would have been encouraged.

A wide range of uses are indicated by these imported plants, including firewood (*Barringtonia*, *Hernandia* and *Hibiscus*), seed endocarps of *Aleurites* used for light (Buck 1957), food (*Cocos*, *Cordyline* and *Musa*) and fibre (*Hibiscus*) for making cordage.

Relic *Cordyline* is found today at prehistoric gardening locales along the margin of the plateau and was introduced as early as A.D. 980 (Weisler 1995:Table 2, Beta-45603). Once this plant is established, it does not require human intervention and thus could act as a dependable source of food for residents and visitors alike. On an island such as Henderson, with poor soils and undependable rainfall, *Cordyline* provided a small, but reliable addition to the subsistence base.

It is unlikely that the giant swamp taro (*Cyrtosperma*) ever grew on the island because there is no habitat conducive for its growth. It is more probable that some transported commodities were bundled in swamp taro leaves - which attain lengths of up to 2 m - and that these wrappings were subsequently used to cover earth ovens during cooking. Indeed, leaves were found associated with ovens at two sites.

Faunal remains

Nearly 4000 Pacific rat bones were recovered from all excavated habitation sites; rats arrived on Henderson probably by the early 10th century (Weisler 1995:Table 2, Beta-59005) - that is, sometime after initial settlement. It is unlikely that pig would have survived in Henderson's harsh environment for very long, but four bones, representing at least three individuals, were found in prehistoric contexts. A humerus, a toe bone, an incisor and a tusk fragment suggest that entire animals were brought to the island and not just the portions associated with most meat. The exact date of introduction is, at present, uncertain.

Island chronology and inter-island voyaging

Some 31 radiocarbon samples have been analysed thus far (see Weisler 1995:388-389 for analytical details) and provide a good overview of the chronology of island colonisation, expansion of settlements to all habitable coastlines, long-distance inter-island communication and eventual island abandonment. Figure 9.8 illustrates the corpus of radiocarbon age determinations plotted as the oldest range at two sigma by century. Note that the dip at A.D. 1300 is an artefact of the sampling scheme where

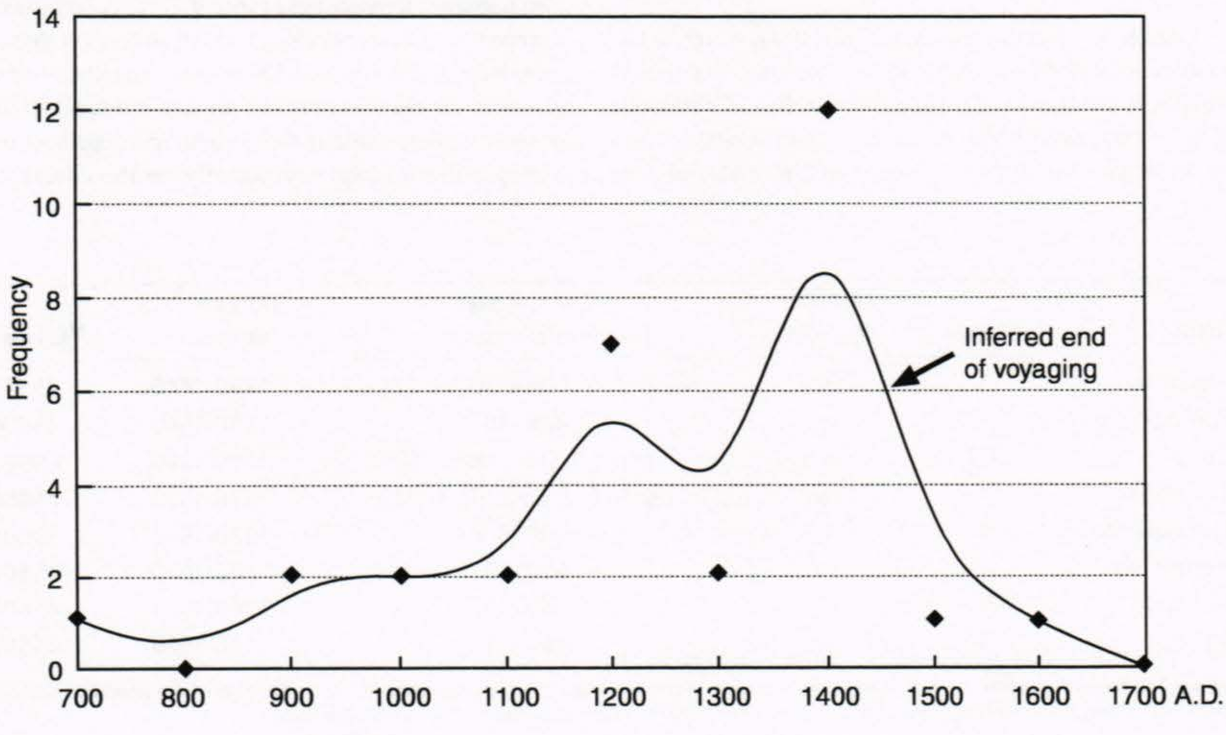

FIGURE 9.8. Radiocarbon age determinations for Henderson Island. Dates plotted by the oldest range by century.

samples were selected from the bottom and top cultural layers of most cave and rockshelter habitation sites, as well as seven locations at the large coastal midden along the north beach, and gardening locales on the north and east plateau margins. Additional dating samples were chosen that were clearly associated with imported artefacts, plant remains and the bones of introduced animals. I identify three important chronological events. First, established settlement, which was continuous thereafter, begins by *ca* A.D. 1050 (9.7% of all dates are at or before this time). Older dates of discovery and exploitation events, if not colonisation, were found at the large north coast midden which is inland of a pass through the reef. The area is sheltered from the southeast trades being in the lee of 33 m high cliffs; in essence, the ideal, most protected habitation locale. The second oldest date comes from a high overhang shelter on the east beach. Several kilos of turtle bone suggest that the site was occupied primarily to harvest sea turtles when they came ashore to nest; use of previously untapped resources should be identified early in a colonisation sequence (Anderson 1995).

Third, the period of inter-island voyaging ended by *ca* A.D. 1450 which is defined here as the tapering-off of imports and not necessarily the absolute disappearance of all imported artefacts. Two factors suggest that assigning an absolute time to the cessation of voyaging is problematic. First, curation of superior artefacts such as fine-grained basalt adzes and vesicular oven stones were probably used for a period of time after inter-island voyaging ended. Second, it is necessary to accept the fact that post-depositional alterations do displace small objects in sandy substrates. Burrowing crabs and birds, tree falls that uproot deposits, and subsequent prehistoric habitation where residents excavated pits for ovens and trash, are all responsible for displacing cultural material. Under these circumstances, it is unlikely the end of voyaging will be signaled by a *stratigraphically abrupt* end to all imported materials. It is therefore the *trends in each habitation site sequence* that is of most interpretive value.

By dating the top cultural layer of most habitation sites, the period of island abandonment is fixed at sometime during the 17th century. This is strengthened further from historical observations by three crew of the *Almiranta* who rowed ashore at the northwest beach in a small dingy on 29 January 1606 and reported that the island was "only inhabited by birds" (Quiros 1904:193).

In summary, Henderson was initially settled by A.D. 1050, inter-island voyaging ended about A.D. 1450, with island abandonment following less than two centuries later. It is significant that the earliest habitation sites date to the 12th century on Mangareva and 14th century on Pitcairn. However, on Henderson, artefacts from Mangareva appear as early as A.D. 1000 (Weisler 1995:Table 2, Beta-59983) and from Pitcairn, about A.D. 900 (Weisler 1995:Table 2, Beta-59005), thus extending the chronology for both islands by several centuries.

SUMMARY AND CONCLUSIONS

The Mangareva-Pitcairn group interaction sphere

The prehistory of Henderson presents a striking example of the role of inter-island voyaging in sustaining small, marginal human populations on ecologically-impoverished islands. Once colonised, Henderson was part of an interaction sphere which included Pitcairn and perhaps several islands of Mangareva. Aside from the obvious advantages of connecting small communities poor in certain resources to their parent population (Alkire 1965; see also Cherry 1985 and Kirch 1988), the disparity in vital industrial and prestigious products - such as fine-grained basalt and perhaps turtles and red features which were depleted or absent at the homeland - was a real incentive for two-way movement of commodities. Indeed, the more marginal communities were not merely on the receiving end, but had an important reciprocal role to play within the interaction sphere (Fig. 9.9; Table 9.3). Detailed geochemical studies have shown that Pitcairn's inexhaustible fine-grained basalt at Tautama was transported as raw material and probably in finished form as well to Henderson and Mangareva (see Chapter 13). Huge stocks of pearl-shell in the Mangareva lagoon provided an important raw material for fishhook manufacture to Pitcairn and Henderson. This is the first archaeologically-documented, two-way movement of exotic commodities in East Polynesia. The fact that oven stones recovered on Henderson came from Mangareva as well as Pitcairn suggest, perhaps, the direct transfer of vesicular basalt from Mangareva to Henderson. If space on voyaging canoes was at a premium - as experimental sailing trials suggest - it seems unlikely that oven stones would be carried to Pitcairn (where they are in unlimited abundance), then on to Henderson. At least, this scenario provides some clues as to the directionality of the interaction sphere. By the same token, it is logical to assume that the fine-grained basalt, volcanic glass and oven stones on Pitcairn were transferred directly to Henderson - a distance of about 100 km, instead of the more than 800 km a round-trip to Mangareva would entail.

In addition to volcanic artefacts and black-lipped pearl-shell, vital plants were introduced as part of the colonisation and settlement process. Food, fibre, light and firewood uses are indicated. Because of the general west-to-east

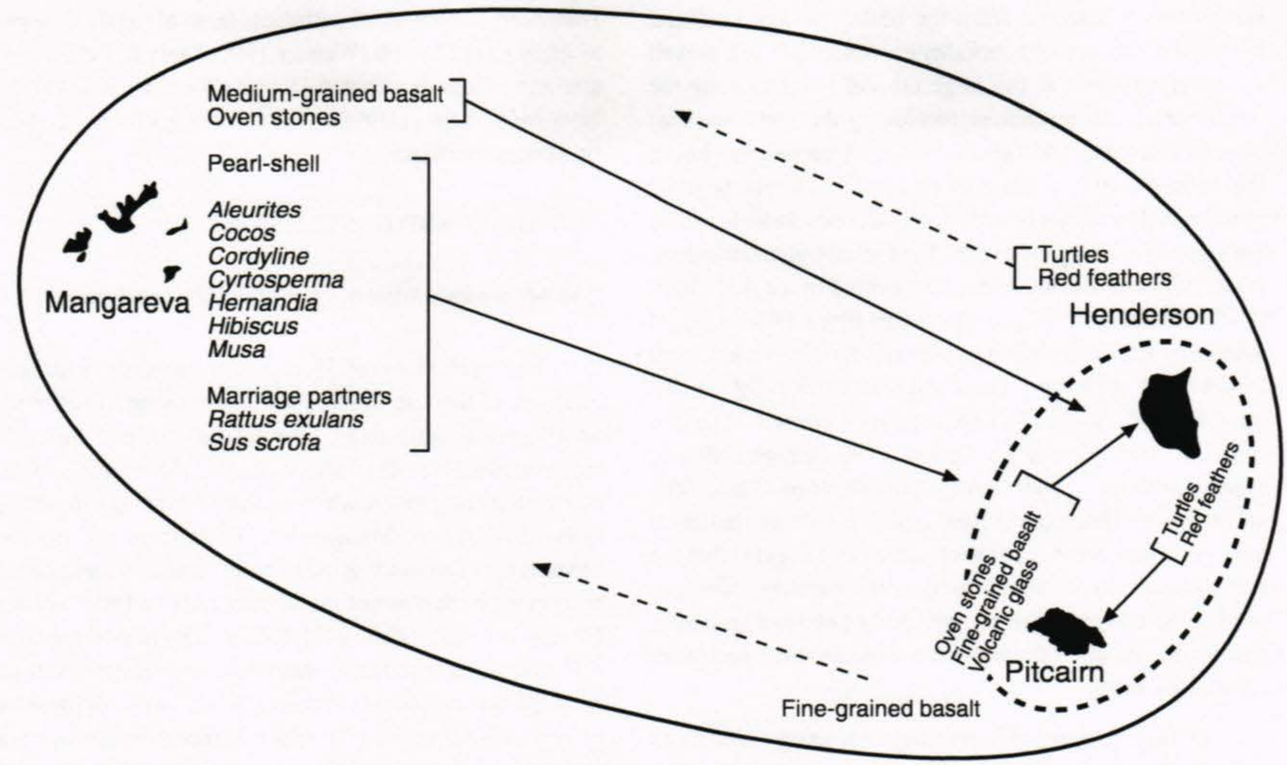

FIGURE 9.9. The southeast Polynesia interaction sphere identified by archaeological material recovered from Henderson and Pitcairn islands, Aukena and several unspecified islands in Mangareva. A more comprehensive approach to sourcing imports has identified not only fine-grained basalt artefacts (such as adzes, hammerstones and debitage), but oven stones, plant remains, and the bones of pigs and rats - the latter two of which were known to be introduced across the Pacific. Prestige items, including red feathers and turtles, were probably important exchange commodities from Henderson, although this has not been ascertained archaeologically.

colonisation of the Pacific islands, Mangareva was undoubtedly the original source of the cultigens brought to the Pitcairn group. However, the archaeologically-identified plant remains on Henderson could have come from Mangareva and Pitcairn over the course of 400 years of inter-island communication. The same could be said of the imported fauna - pigs and rats.

With small isolated human populations, genetic redundancy is a real problem that could facilitate the spread of sickness and disease, while generally lowering the overall health of the community. It is reasonable to assume that in this context, periods of drought and low food productivity, and dwindling bird populations that were a major food source in the early settlement period (Wragg 1995; Wragg and Weisler 1994), ultimately put the human population at extreme and fatal risk during the cessation of inter-island voyaging. Without the 'lifeline' to Mangareva - and the addition of food and marriage partners - Henderson and Pitcairn could not sustain their communities. Thus, Irwin is able to identify a whole set of such island communities, a category or set of islands found throughout the Pacific, but especially in Polynesia (Irwin 1992:175).

Reasons for the end of voyaging

As papers in this volume have demonstrated, archaeological interaction studies for the eastern Pacific are fast accumulating data sets for many archipelagoes. While it will be advantageous to have detailed studies from at least several sites from each island group, it is possible now to at least address some of the areas that could have led to a decline and the eventual cessation of inter-archipelago voyaging in East Polynesia. Here, I define voyaging on the grand scale that involves transfer of commodities between archipelagoes for we know from historical accounts and, indeed, modern observations of traditional craft, that movement within island groups is still practiced today. I address four areas of concern that, together, suggest possibilities for the end of voyaging in late prehistory.

Landscape degradation

In contrast to continents, islands are relatively small, circumscribed land units that require active management for sustainability. With a wide range of geology, soils, flora,

Variable*	Descriptive Summary
Content: Imports & Exports	Fine-grained basalt (cores, adzes, hammerstones); coarse-grained basalt (abrading stones); vesicular basalt (oven stones); volcanic glass (flakes, cores); pearl-shell *(Pinctada margaritifera)* (whole valves, fishhooks); cultigens such as *Aleurites, Cocos, Cordyline, Cyrtosperma, Hernandia, Hibiscus* and *Musa* (leaves, seeds, fruit, wood); fauna (pig, Pacific rat, turtles?, red feathers?, probably marriage partners). See Fig 9.9.
Magnitude	Rank-order abundance by weight of volcanic artifacts: fine-grained basalt, oven stones, coarse-grained basalt, volcanic glass; difficult to quantify plant remains and fauna, but adds to overall magnitude.
Diversity	High diversity of predominantly utilitarian items (both raw material and finished forms); few valuables or luxury items (such as turtle meat and red feathers).
Network Size	Two geographic scales: short–involving only Henderson and Pitcairn (ca. 100 km, 1-way); and long–between the Pitcairn group and Mangareva (ca. 400 km, 1-way)
Directionality	Archaeological evidence: Mangareva to Pitcairn; Mangareva to Henderson; Pitcairn to Mangareva, Pitcairn to Henderson; ethnographic evidence: Henderson to Mangareva; Henderson to Pitcairn; oral history: Mangareva to Tuamotus, Pitcairn group & Rapa Nui.
Symmetry	Archaeological evidence at colonisation process: Mangareva to Pitcairn group; during inter-island voyaging: Pitcairn to Henderson, Mangareva to Henderson, Mangareva to Pitcairn.
Time Span	400 - 500 years.
Centralization	Adze production centred at Pitcairn. Greatest natural diversity of imports in Mangareva.
Complexity	Not simple, but only somewhat complex.

* variables after Plog (1977).

TABLE 9.3. A descriptive summary of the Mangareva-Pitcairn group interaction sphere.

and terrestrial and marine biota, unsettled islands were a great incentive to voyage ever farther to the east in search of previously untapped and plentiful resources (Anderson 1996). Yet, aside from the initially large sea bird colonies and plentiful marine foods, much of the economically-useful plants had to be imported. For long-term sustainability, tree crops were planted and large tracts of land cleared for planting tuberous crops. In essence, islands were transformed to meet the mental template of the colonist's homeland. In the sort run, landscape modification enhanced productivity of the terrestrial environment by clearing land for cultivation. However, the long-term effects of shifting cultivation and subsequent agricultural intensification destroyed habitat for native land birds (Steadman 1995) and nesting sea bird colonies. Forests were replaced by terminal grasslands and ferns, and scarred landscapes required mulching and irrigation to exact ever greater yields from nutrient-depleted soils. The forest continually gave way to further demands of a growing population. Consequently, when human populations were at their highest, soil productivity and marine stocks were at their nadir. The 'costs' of building and maintaining large voyaging canoes with numerous crew members and commodities for exchange was no longer considered a worthwhile effort under extreme conditions at home.

The effects of population increase

As small circumscribed islands experienced increased landscape degradation in later prehistory, it was unfortunate that human populations grew inversely to the potential of the land to support its inhabitants (see Bahn and Flenley 1992 for the example of Easter Island). Many land birds were now extinct, sea birds moved their remnant colonies to inaccessible locales on off-shore islands, the bounties of the sea were now reduced to diminutive shellfish (see Kirch *et al.* 1995 for Mangaia, southern Cook Islands) and declining sizes and abundance of fish. Dwindling resources at times of population increase during later prehistory led to intensified social conflicts such as warfare, chiefly competition exacted even more productivity from the land. Buck reports instances of cannibalism on Mangareva (1938) and at least ritual consumption of human flesh on Mangaia in late prehistory which appears to have some archaeological evidence (Anderson and Anton 1993). The notion of voyaging to new lands with plentiful resources or, maintaining existing inter-archipelago contacts for utilitarian objects, became increasingly untenable.

Evolving social conditions

The initial settlement of the widely-scattered and diverse islands of the Pacific may well have been fueled by the desire to locate landfalls with abundant and untapped resources and, in the example of Mangareva and the Pitcairn group, continued and regular contact served as a resource-balancing lifeline that connected the string of small, individually-unsustainable communities. With increasing population and decreasing soil fertility in an island group with a restricted and steep landscape, Mangareva was not in an advantageous position to sponsor the building and equipping of long-distance voyaging canoes. Additionally, deforestation limited the amount of trees suitable for canoe construction and early European visitors to Mangareva witnessed the use of crude rafts and absence of canoes - even for close inter-island travel (Buck 1938).

Like many Pacific islands, Mangareva - with its 25 km^2 of land, *ca* 25 km wide lagoon, large sea bird populations and rich coastal alluvial soils, would initially have been a reasonably balanced resource locale for human settlement (Weisler 1996a, b). Yet, as an 'Open Society' (Goldman 1970), Mangareva was characterised in late prehistory as having limited productive land area, environmental hazards such as cyclones and drought and landscape degradation. The increasingly uneven distribution of resources set the stage for intense competition and warfare. For example, the western and eastern sides of Mangareva island, divided along the north-south trending central mountain ridge, separated the resource-rich lagoon and better-watered coastal lands of Rikitea (the seat of the paramount chief), from the ocean-facing reefs and sloping lands of Taku district. Wars were fought repeatedly between Taku and Rikitea for supreme power (Goldman 1970:151) During this time, status and rank were acquired through conflict and warfare, and food-producing land was the supreme expression of wealth (Buck 1938:146, 199; Goldman 1970:150). The emphasis on outward-looking island expansion and maintenance of satellite communities on Henderson and Pitcairn during early settlement was replaced by homeland-focussed staple-based production of upland dryland crops (including breadfruit), while production along the coastal alluvial flats was intensified by irrigation. Local production and competition for access to the limited fertile soils and dwindling marine resources, then, formed the basis of status and rank.

Climate change

It is unlikely that one cause is ultimately responsible for the end of voyaging in the eastern Pacific in general, and southeast Polynesia specifically. However, with increasing populations on islands that were experiencing their lowest terrestrial and marine productivity, a change in climate that produced overall stormier sea conditions may have contributed a small, but additional condition that lead to the end of voyaging. This is especially true in the region of Mangareva and the Pitcairn group where, despite its subtropical climate, does experience more frequent periods of harsh weather than its counterpart, the Hawaiian Islands, at the same latitude in the northern hemisphere. (During my five months on Henderson, I experienced a severe typhoon and two hail storms!) It is perhaps the lowering of world temperatures by *ca* 1.5°C during the Little Ice Age, *ca* A.D. 1500 - 1850 (Grove 1988; Lamb 1977; see also Jones and Bradley 1995:657-658) that *contributed* to shift the balance away from long-distance voyaging. While Bridgeman (1983) believes that the changing weather conditions of the Little Ice Age were a greater deterrent to voyaging than most believe, the "effects of increased weather variability, increased storminess, erratic trade winds, and limited clear skies" (Bridgeman 1983:203) during the Little Age Ice, are difficult to completely ignore when considering the reasons for the decline of voyaging in southeast Polynesia.

Despite its label as a 'mystery' island - one that has evidence of prehistoric settlement but was found abandoned at European contact - Henderson Island, viewed in a regional perspective, has much to offer in terms of understanding the fundamental role of inter-archipelago voyaging in sustaining small human groups on isolated islands, and how voyaging - i.e., inter-societal communication - can greatly influence the archaeological record and our interpretations of it.

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REFERENCES

Alkire, W. 1965. Lamotrek Atoll and Socio-economic Ties. *Illinois Studies in Anthropology* 5. Urbana, University of Illinois Press.

Anderson, A. 1995. Current approaches in East Polynesian colonisation research. *Journal of the Polynesian Society* 104:110-132.

Anderson, A. 1996. Adaptive voyaging and subsistence strategies in the early settlement of East Polynesia. In T. Akazawa and E.J.E. Szathmáry (eds), *Prehistoric Mongoloid Dispersals*, pp. 359-373. Oxford, Oxford University Press.

Anderson, P. and S. Anton. 1993. Human bone modification?: an island example and its implications. Paper presented at the 58th annual meeting of the Society for American Archaeology, St. Louis, Missouri.

Bahn, P. and J. Flenley. 1992. *Easter Island, Earth Island.* London, Thames and Hudson.

Bellwood, P. 1978. Archaeological Research in the Cook Islands. *Pacific Anthropological Records* 27. Honolulu, Bernice P. Bishop Museum.

Benton, T. and T. Spencer (eds). 1995. *The Pitcairn Islands: Biogeography, Ecology and Prehistory.* London, Academic Press.

Bettinger, R., M. Delacorte and R. Jackson. 1984. Visual sourcing of central eastern California obsidians. In R. Hughes (ed), Obsidian Studies in the Great Basin, pp. 63-78. *Contributions of the University of California Archaeological Research Facility* Number 45. Berkeley.

Bridgeman, H.A. 1983. Could climatic change have had an influence on the Polynesian migrations? *Palaeogeography, Palaeoclimatology, Plalaeoecology* 41:193-206.

Brousse, R. and G. Guille. 1974. Géologie et pétrologie des iles Gambier. *Cahiers du Pacifique* 18:159-245.

Brousse, R., J-P Keller and P. Larroque. 1974. Micromorphologie de la bordure des dykes. *Cahiers du Pacifique* 18:265-275.

Buck, P.H. 1938. Ethnology of Mangareva. *Bernice P. Bishop Museum Bulletin* 157. Honolulu.

Buck, P.H. 1957. *Arts and Crafts of Hawaii.* Bernice P. Bishop Museum Special Publication 45. Honolulu.

Carter, R.M. 1967. The Geology of Pitcairn Island, South Pacific Island. *Bernice P. Bishop Museum Bulletin* 231. Honolulu.

Cherry, J.F. 1985. Islands out of the stream: isolation and interaction in early East Mediterranean insular prehistory. In A. B. Knapp and T. Stech (eds), Prehistoric Production and Exchange: The Aegean and Eastern Mediterranean, pp.12-29. *Institute of Archaeology, University of California Monograph* 25. Los Angeles.

Cleghorn, P.L. 1982. The Mauna Kea Adze Quarry: Technological Analyses and Experimental Tests. Ph.D. thesis, University of Hawaii.

Coeroli, M. 1985. Exploitation of mother-of-pearl and pearls. In *Proceedings of the Fifth International Coral Reef Congress Tahiti, 27 May-1 June 1985*, Volume 1, pp. 372-377. French Polynesian Coral Reefs, Moorea, French Polynesia, Antenne Museum-EPHE.

Coeroli, M., D. de Gaillande, J. Landre and D. Coatanea. 1984. Recent innovations in cultivation of molluscs in French Polynesia. *Aquaculture* 39:45-67.

Davidson, J.M. 1972. Archaeological investigations on Motutapu Island, New Zealand. Introduction to recent fieldwork and some recent results. *Records of the Auckland Institute and Museum* 9:1-14.

Duncan, R.A. and I. McDougall. 1976. Linear volcanism in French Polynesia. *Journal of Volcanology and Geothermal Research* 1:197-227.

Emory, K. 1928. Stone implements of Pitcairn Island. *Journal of the Polynesian Society* 37:125-135.

Emory, K. 1939. Archaeology of Mangareva and Neighboring Atolls. *Bernice P. Bishop Museum Bulletin* 163. Honolulu.

Finney, B. 1977. Voyaging canoes and the settlement of Polynesia. *Science* 196:1277-1285.

Florence, J., S. Waldren and A.J. Chipstow-Lusty. 1995. The flora of the Pitcairn Islands: a review. *Biological Journal of the Linnean Society* 56:79-119.

Gathercole, P. 1964. Preliminary Report on Archaeological Fieldwork on Pitcairn Island January-March 1964. Manuscript, Department of Anthropology, University of Otago, Dunedin, New Zealand.

Goldman, I. 1970. *Ancient Polynesian Society.* Chicago, University of Chicago Press.

Green, R.C. 1959. Pitcairn Island fishhooks in stone. *Journal of the Polynesian Society* 68: 21-22.

Green, R.C. 1960. Preliminary Report for the American Museum of Natural History on Archaeological Research in the Gambier Isles (Mangareva) July 2, 1959 to December 6, 1959. Report, Library, University of Otago, Dunedin, New Zealand.

Green, R.C. ms. Mangarevan Fishhooks. Manuscript, Department of Anthropology, University of Auckland.

Grove, J.M. 1988. *The Little Ice Age.* London, Methuen.

Hather, J. 1991. The identification of charred archaeological remains of vegetative parenchymous tissue. *Journal of Archaeological Science* 18:661-675.

Heyerdahl, T. and E.N. Ferdon Jr. (eds). 1961. Reports of the Norwegian Archaeological Expedition to Easter Island and the East Pacific, Volume 1, Archaeology of Easter Island. *Monographs of the School of American Research and the Museum of New Mexico* 24(1), Santa Fe.

Heyerdahl, T. and A. Skjølsvold. 1961. Artifacts collected on certain islands in Eastern Polynesia. In T. Heyerdahl and E.N. Ferdon Jr. (eds), Reports of the Norwegian Archaeological Expedition to Easter Island and the East Pacific, Volume 2, Miscellaneous Papers, pp. 115-168. *Monographs of the School of American Research and the Museum of New Mexico* 24(1).

Howard, A. 1967. Polynesian origins and migrations, a review of two centuries of speculation and theory. In G.A. Highland, R.W. Force, A. Howard, M. Kelly and Y.H. Sinoto (eds), Polynesian Culture History, Essays in Honor of Kenneth P. Emory, pp. 45-101. *Bernice P. Bishop Museum Special Publication* 56. Honolulu.

Irwin, G. 1981. How Lapita lost its pots: the question of continuity in the colonisation of Oceania. *Journal of the Polynesian Society* 90:481-494.

Irwin, G. 1989. Against, across, and down the wind: a case for the systematic exploration of the remote Pacific island. *Journal of the Polynesian Society* 98:167-206.

Irwin, G. 1992. *The Prehistoric Exploration and Colonisation of the Pacific.* Cambridge, Cambridge University Press.

Jones, P.D. and R.S. Bradley. 1995. Climate variations over the last 500 years. In R.S. Bradley and P.D. Jones (eds), *Climate Since A. D. 1500*, pp. 649-665. London, Routledge.

Kay, E. 1984. Patterns of speciation in the Indo-West Pacific. In F.J. Radovsky, P.H. Raven and S.H. Sohmer (eds), Biogeography of the Tropical Pacific: Proceedings of a Symposium, pp.15-31. *Bernice P. Bishop Museum Special Publication* 72. Honolulu.

Kirch, P.V. 1988. Long-distance exchange and island colonization: the Lapita case. *Norwegian Archaeological Review* 21:103-117.

Kirch, P. and T.L. Hunt (eds). 1988. Archaeology of the Lapita Cultural Complex: A Critical Review. *Thomas Burke Memorial Washington State Museum Research Report* No.5. Seattle.

Kirch, P.V, D.W. Steadman, V.L. Butler, J. Hather and M.I. Weisler. 1995. Prehistory and human ecology in Eastern Polynesia: excavations at Tangatatau rockshelter, Mangaia, Cook Islands. *Archaeology in Oceania* 30:47-65.

Lamb, H.H. 1977. *Climate, Present, Past and Future.* London, Methuen.

Lavachery, H. 1936. Contribution a l'etude de l'archeologie de l'ile de Pitcairn. *Bulletin de la Société des Americanistes de Belgique* 19:3-42.

Levison, M.R., G. Ward and J.W. Webb. 1973. *The Settlement of Polynesia: A Computer Simulation.* Canberra, Australian National University Press.

Matisoo-Smith, E. 1994. The human colonisation of Polynesia. A novel approach: genetic analyses of the Polynesian rat (*Rattus exulans*). *Journal of the Polynesian Society* 103:75-87.

Preece, R.C. 1995. Systematic review of the land snails of the Pitcairn Islands. *Biological Journal of the Linnean Society* 56:273-307.

Quiros, P.F.de. 1904. *The Voyages of Pedro Fernandez de Quiros, 1595-1606.* 2 volumes. Translated and edited by Clements Markham. London, Hakluyt Society.

Rehder, H.A. and J.E. Randall. 1975. Ducie Atoll: Its History, Physiography and Biota. *Atoll Research Bulletin* 183. Washington, D.C., Smithsonian Institution.

Routledge, K.S. 1919. *The Mystery of Easter Island.* London, Sifton, Praed and Co.

Schubel, S.E. and D.W. Steadman. 1989. More Bird Bones from Polynesian Archaeological Sites on Henderson Island, Pitcairn Group, South Pacific. *Atoll Research Bulletin* 325. Washington, D.C., Smithsonian Institution.

Seurat, L.G. 1904. Sur les anciens habitants de l'ile Pitcairn. *L'Anthropologie* 15:369-372.

Sharp, A. 1956. Ancient Voyagers in the Pacific. *Polynesian Society Memoir* 32. Wellington, The Polynesian Society.

Sinoto, Y. 1983. An analysis of Polynesian migrations based on the archaeological assessments. *Journal de la Société des Océanistes* 76:57-67.

Steadman, D.W. 1995. Prehistoric extinctions of Pacific island birds: biodiversity meets zooarchaeology. *Science* 267:1123-1131.

Steadman, D.W. and S.L. Olson. 1985. Bird remains from an archaeological site on Henderson Island, South Pacific: man-caused extinctions on an "uninhabited" island. *Proceedings of the National Academy of Sciences USA* 82:6191-6195.

Terrell, J. 1986. *Prehistory in the Pacific Islands.* Cambridge, Cambridge University Press.

Valeri, V. 1985. *Kingship and Sacrifice, Ritual and Society in Ancient Hawaii.* Chicago, University of Chicago Press.

Walter, R. 1990. The Southern Cook Islands in Eastern Polynesian Prehistory. Ph.D. thesis, University of Auckland.

Weisler, M.I. 1993a. Long-distance Interaction in Prehistoric Polynesia: Three Case Studies. Ph.D. thesis, University of California, Berkeley.

Weisler, M.I. 1993b. Provenance studies of Polynesian basalt adze material: a review and suggestions for improving regional data bases. *Asian Perspectives* 32:61-83.

Weisler, M.I. 1994. The settlement of remote Polynesia: new evidence from Henderson Island. *Journal of Field Archaeology* 21:83-102.

Weisler, M.I. 1995. Henderson Island prehistory: colonization and extinction on a remote Polynesian island. *Biological Journal of the Linnean Society* 56:377-404.

Weisler, M.I. 1996a. An archaeological survey of Mangareva: implications for regional settlement models and interaction studies. *Man and Culture in Oceania* 12:61-85.

Weisler, M.I. 1996b. Taking the mystery out of the Polynesian 'mystery' islands: a case study from Mangareva and the Pitcairn Group. In J. Davidson, G. Irwin, F. Leach, A. Pawley and D. Brown (eds), Oceanic Culture History, Essays in Honour of Roger Green, pp.615-629. *New Zealand Journal of Archaeology Special Publication*, Dunedin.

Weisler, M.I., T. Benton, M. de L. Brooke, P.J. Jones, T. Spencer and G. Wragg. 1991. The Pitcairn Islands scientific expedition (1991-1992): first results, future goals. *Pacific Science Association Information Bulletin* 43:4-8.

Weisler, M.I. and D.A. Clague. 1997. Characterization of archaeological volcanic glass from Oceania: the utility of three techniques. In M.S. Shackley (ed), Archaeological Obsidian Studies: Method and Theory. *Advances in Archaeological and Museum Sciences* 3. New York, Plenum Press.

Weisler, M.I. and Woodhead, J.D. 1995. Basalt Pb isotope analysis and the prehistoric settlement of Polynesia. *Proceedings of the National Academy of Sciences U. S. A.* 92:1881-1885.

Woodhead , J.D. and M.T. McCulloch. 1989. Ancient seafloor signals in Pitcairn Island lavas and evidence for large amplitude, small length-scale mantle heterogeneities. *Earth and Planetary Science Letters* 94:257-273.

Wragg, G.M. 1995. The fossil birds of Henderson Island, Pitcairn Group: natural turnover and human impact, a synopsis. *Biological Journal of the Linnean Society* 56:405-414.

Wragg, G.M. and M.I. Weisler. 1994. Extinctions and new records of birds from Henderson Island, Pitcairn Group, South Pacific Ocean. *Notornis* 41:61-70.